EFFECT OF NON-ENZYMATIC BROWNING OF BREAD ON THE GROWTH RATE OF CHICKS

By

FARZANEH KATKHORDEH

Bachelor of Science

University of Arkansas

Fayetteville, Arkansas

1983

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1987

EFFECT OF NON-ENZYMATIC BROWNING
OF BREAD ON THE GROWTH
RATE OF CHICKS

Thesis Approved:

Sue Knight
Thesis Adviser

Christie I. Hansen

Robert Teeter

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

The author wishes to express her sincere thanks and appreciation to Dr. Sue Knight, major adviser, for her thoughtfulness, constant guidance and support throughout the study. Appreciation is also expressed to the members of the advisery committee, Dr. Christa Hanson, and Dr. Robert Teeter, for giving of their expertise during this study.

The author wishes to thank Dr. Morrison for his assistance in developing the statistical analysis of this study. Also special thanks is expressed to Dr. Mort for the use of his gas chromatograph.

A special note of appreciation must be given to the College of Home Economics for naming me as recipient of the Mary Leidigh Scholarship. It came when the need was great.

My special thanks, love and gratitude is given to my husband, Feridoon Mehdizadegan for his constant support and love. Many thanks to my lovely daughter, Ida Mehdizadegan, for her patience throughout her mom's graduate work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The oldest fireplace discovered, that of homopekinensis is about 400,000 years old. Since at least as early as that time, man has used fire to cook, fry, bake and roast his food. Discovered by chance, the application of fire for food preparation was rapidly reinforced by the interesting new taste and flavors thus produced. As a consequence of heating, food preservation was improved and toxicity greatly reduced. Heating also enabled man to enlarge his choice of food enormously, since many foods became more wholesome for man after heat treatment. It is, therefore, no exaggeration to state that primitive man "invented" the Maillard reaction to improve his eating pleasure. This in turn played an important role in the emergence of civilization. Eating pleasure guided prehistoric man when he was experimenting with food and fire, and the beneficial or detrimental physiological effects were only by-products of his desire for new flavor sensations. Thus, increased food enjoyment was the basic justification for browning of foods in the Maillard reaction (1).

During heat treatment such as frying, roasting, and baking, the Maillard reaction improves food in taste, flavor and color. In the drying of milk or storage of instant potatoes, on the other hand, the Maillard reaction gives unfavorable effects, such as decreased nutritional value and color deterioration (2).

Significance of the Problem

Food, with very few exceptions, is a chemically complex medium. Preparation and storage procedures cause changes in temperature, pH, water activity, and composition, giving rise to new compounds as a result of chemical reactions.

The Maillard reaction (also called non-enzymatic browning) is a heat induced reaction between amino acids of proteins and carbonyl groups of reducing sugars. The reaction yields a brown color and flavor changes, but also binds the amino acids and sugars involved (3). In spite of this protein binding, food scientists have generally concluded that the actual nutritional loss associated with browning of foods is negligible (4).

To test this conclusion, Knight, Hanson, and Teeter (5) looked at the effect of feeding browned bread ingredients on chick growth. An oven-heated feed composed of flour, oil, yeast, sugar (glucose), dried eggs, vitamins, and minerals was fed to chicks with ingredient amounts adjusted so as to provide an adequate total diet. They found that if the feed was left unbrowned, the chicks gained weight rapidly; but the chicks fed the browned feeds whether lightly browned or darkly browned gained little, if at all; and they did not eat.

In a similar chick study, Jagannathan (6) investigated the effect of four different sugars (fructose, sucrose, and two different brands of glucose) with the feeds oven heated to a uniform temperature of about 113° C. Jagannathan also worked with browned bread ingredients; but, like Knight, Hanson, and Teeter (5), she did not make the ingredients into loaves of bread. She found that the feed with sucrose produced the most growth in the chicks and the fructose feed produced

the least. The two glucoses, each from a different supplier, produced different growths, although both were described as glucose monohydrate.

There is agreement among many researchers (7-14) that the amino acid, lysine, is the amino acid most readily bound in browning during baking (15). Lysine is essential for humans and chicks but is limited in cereal protein foods (16). Many population groups depend heavily on cereal proteins, however, a significant loss of lysine upon heating may occur in these proteins.

Purpose of Study

The purpose of this study was to investigate the effect of non-enzymatic browning of bread prepared with sucrose or fructose on chicks' growth rate. The objectives of the study were as follows:

1. To determine whether fructose or sucrose in baked bread affected the chicks' growth.

2. To determine whether there was a difference in chick growth when fed bread crust, middle (crumb), entire loaf, or unbaked dry ingredients.

3. To determine whether lysine contents of the different feeds were correlated with chick growth.

4. To determine whether the sugar used or portion of loaf fed affected the amount of feed consumed by the chicks.

Hypotheses

The following hypotheses were postulated for the study:

Hypothesis 1. There will be no significant differences in the growth rate of chicks due to feed treatments of two sugars and four

degrees of browning (crust, middle, whole loaf, and unbaked dry ingredients).

Hypothesis 2. There will be no significant differences in the lysine content of the feeds due to type of sugar or degree of browning.

Hypothesis 3. There will be no significant differences in the amount of feed consumed by the chicks due to sugar, portion of loaf, or unbaked dry ingredients.

Assumptions

The following assumptions were made for this investigation:

1. The growth rate of chicks will reflect the amino acid quality of the feed since chicks are an accepted test animal for lysine assay (16).

2. The experiment will be conducted under controlled conditions.

Limitations

Limitations identified in this study were as follows:

1. Only two different sugars were used:
   a. Sucrose, and
   b. Fructose.

2. The experimental design did not include feeding a bread made from an unbaked dough (to test the effect of just wetting and drying ingredients).

Definitions

Definitions for this study are as follows:

Maillard reaction is a non-enzymatic browning reaction between

amino groups in protein that when heated react with reducing sugars to form brown, insoluble, and enzyme resistant substances (17).

Reducing sugar is a sugar which has an aldehyde or ketone group. All monosaccharides and some polysaccharides have the ability to reduce an alkaline solution of cupric ions without undergoing hydrolysis and are said to be reducing sugar (18).

Essential amino acid is an amino acid that the body can not synthesize in amount sufficient to meet physiological need and must be obtained from foods (19).

Limiting amino acids are the amino acids found in the shortest supply relative to the amounts needed for protein synthesis in the body (20).

CHAPTER II

REVIEW OF LITERATURE

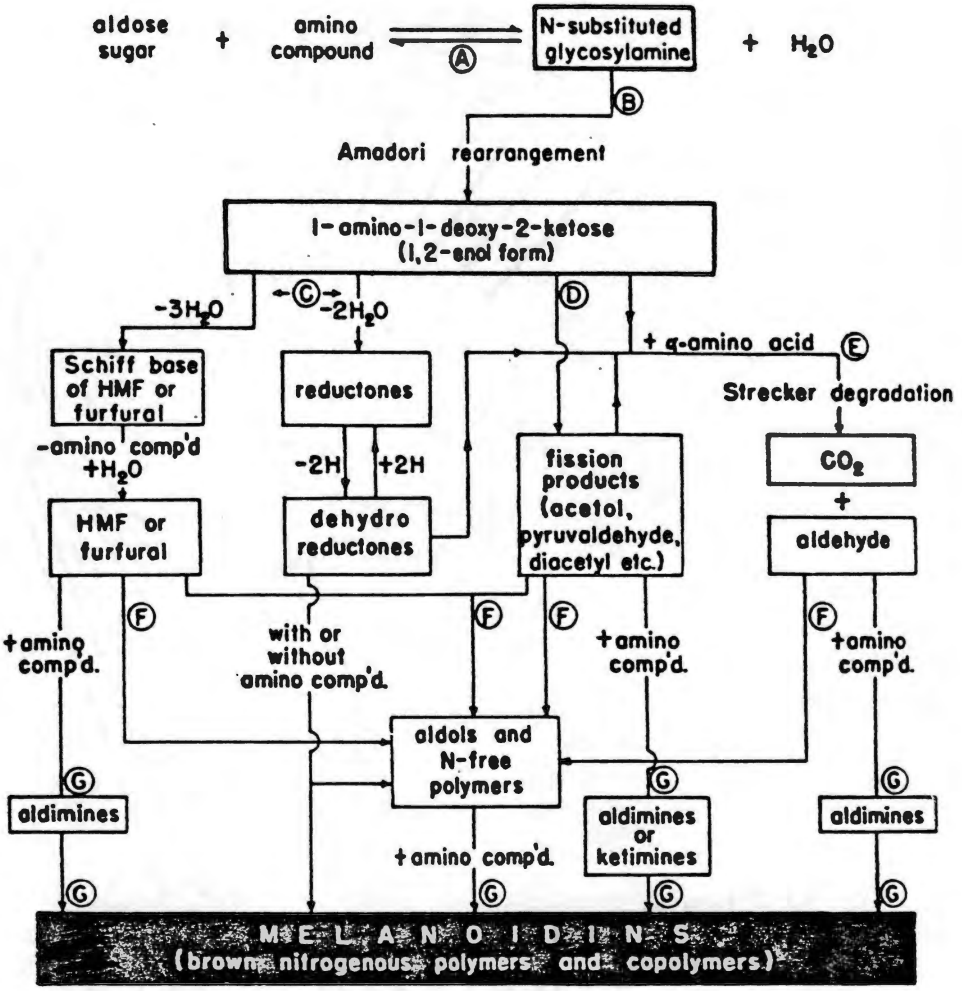
This chapter reviews the scientific basis for the Maillard reaction in foodstuff and on human nutrition. The review covers a summarization of the Maillard reaction model system, effects of physical conditions, negative and positive aspects of this reaction, antioxidative-antimicrobial properties, and effects in baking bread.

Maillard Reaction in Model System

Food processing, preservation and storage cause changes giving rise to new compounds as a result of chemical reactions. The Maillard is one of those reactions. It is a non-enzymatic reaction between amino groups of amines, amino acids, or proteins and carbonyl groups of reducing sugars, resulting in the formation of strongly colored products that have a characteristic brown color and flavor. In 1911 Maillard (21) determined that single amino acids react on warming with reducing sugars to form brown products; therefore, the non-enzymatic browning of protein and carbohydrate containing foodstuffs was named the "Maillard reaction." This reaction can cause the loss of nutritive value during heating or prolonged storage.

Browning in fried or baked food has been studied from chemical, technological, nutritional, and physiological points of view (2, 21). However, widespread knowledge of the health implications is still limited (22).

Lee, Chichester and Lee (Figure 1) summarizes the existing k
ledge about the browning reactions in model systems of carbonyls
amino compounds. Apparently seven different types of reactions oc
during browning (23).



Source: Hodge, J. E.: Chemistry of browning reaction in model systems. J Agric Food Chem. 1:928, 1953.

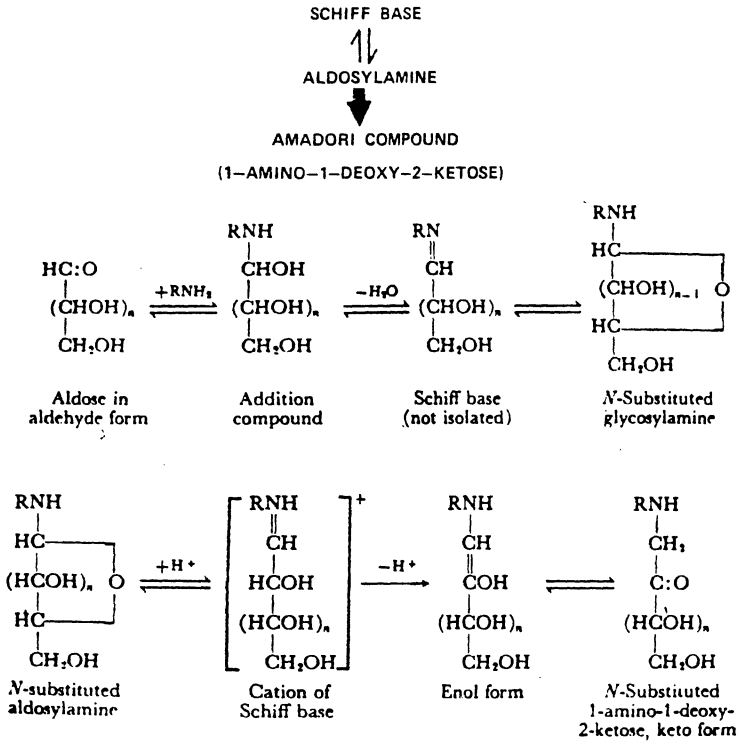
Figure 1. Principal Stages of the Maillard Reaction: Amadori Rearrangement of Glycosylated Proteins. Integration of Known Reactions Leading to Browning in Sugar-Amine Systems

Stages of the Maillard Reaction

I. The Initial Stage. Colorless, but there is formation of pre-melanoidin compounds, amino acids are already lost nutritionally (24). No absorption in the near ultra violet light. Characterized by:

a. Sugar-amine condensation. Reversible, as the glycosylamine can be hydrolyzed back in aqueous solution to the parent components (25), (Figure 2).

b. Amadori rearrangement.



Source: Lewis, V. M. and Lea, C. H.: A note on the relative rates of reaction of several reducing sugars and sugar derivatives with casein. Biochem Biophys Acta. 4:532, 1950.

Figure 2. The Initial Steps of the Maillard Reaction

II. The Intermediate Stage. May be colorless to yellow, with strong absorption in the near ultra violet light (26). Characterized by:

c. Sugar dehydration.

d. Sugar fragmentation.

e. Amino acid degradation. Strecker degradation with the loss of CO_2.

III. The Final Stage. Highly colored (27).

f. Aldol condensation.

b. Aldehyde-amine polymerization formation of heterocyclic compounds.

Effects of Physical Conditions

The physical factors of heat, pH, and amount of moisture present all affect the occurrence and reaction speed of Maillard reaction (25).

Heating

Heat treatment in starches improves digestibility, which is beneficial, but heat causes nutrient losses in protein. The major cause of heat injury appears to be the result of impaired assimilation of one or more essential amino acids. Thus, Maillard browning is produced when reducing sugars are heated with amino acids. It develops slowly at room temperature during foodstuff storage but is greatly activated by rises in temperature, thus its frequent association with heat treatments (25, 28, 29, 30).

Adrian and Favier (31) reported losses of an amino acid by heating a glucose-lysine solution for 25 hours at 120°C or for six hours at

130°C. The addition of premelanoidin, a Maillard intermediate to the glucose-lysine solution increased heating effects autocatalyticly. The lysine loss with and without premelanoidin was respectively, 45%, and 7%. Thus intermediate compounds of the Maillard reaction should not be ignored; they can auto-intensify the effects of heat treatment.

In another study Patton, Hill, and Foreman (32) reported that among the essential amino acids assayed, only lysine, arginine, and tryptophan were inactivated to a significant level by the glucose-heat treatment. However, Greaves, and Morgan (33) found that heated casein could be almost completely restored to its original biological value by the addition of lysine.

Plakas, Lee, Wolke, and Meade (34) studied the effect of Maillard browning in the diet of Rainbow trout (Salmo gairdreri) on growth and amino acid availability. Their results indicated that lysine and arginine showed the greatest loss in the mixture of fish protein isolate and glucose stored for 40 days at 37°C. The apparent digestibility and absorption of lysine was lower in trout fed browned protein than in those fed the control protein.

pH

pH plays an important role in the Maillard reaction. Acidification tends to inhibit browning, and alkalinization greatly heightens its intensity. The pH values that are most detrimental to amino acids range from pH 3 to pH 9 (35). Therefore, natural or artificial acidification of foodstuffs will increase their protein stability, and any alkalinization will expose them to more intense browning (36).

Hydration

The Maillard reaction is maximal at relative humidities between 40-70%, decreasing as the aqueous dilution increases, and becoming inactive in the case of extremely diluted solutions (25, 37, 38). Schroeder, Lacobellis, Lees, and Smith (39) reported that heat treatments in dry medium (roasting, baking) are more damaging than processing in aqueous mediums (autoclaving, pressure cooking).

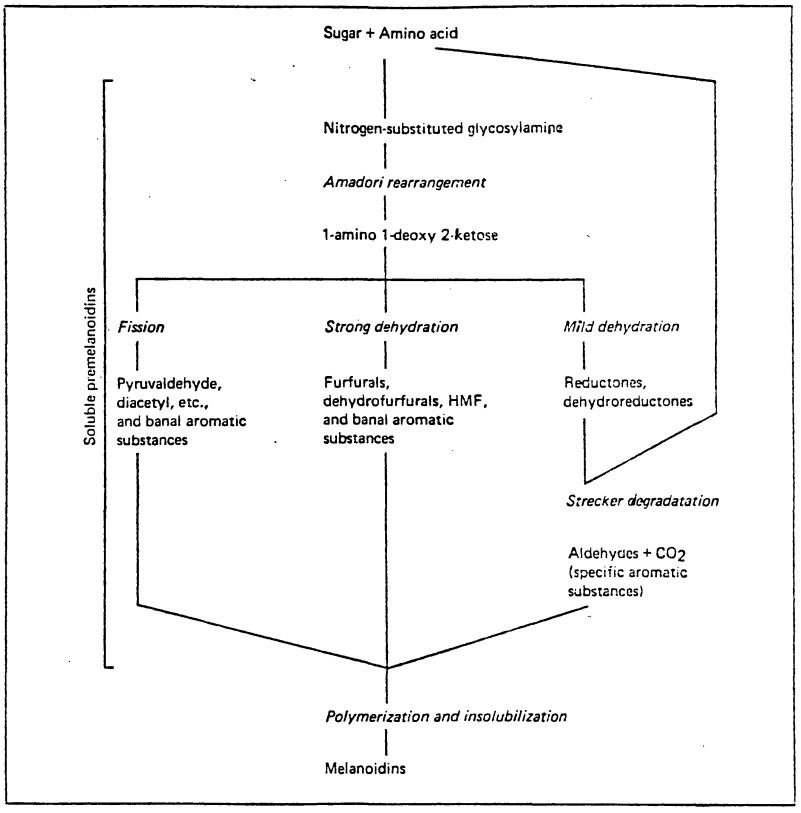
Loncin, Jacqmain, Tutundjlan-Pruvost, Lenges, and Blmbenet (38) concluded that water may have both accelerating and inhibiting effects. This could be partially explained by the fact that the reaction needs water to ensure the mobility of the initial reagents and is consequently favored in poorly hydrated mediums. Water becomes an inhibitor of the reaction when the dehydration stages are reached (Figure 3).

Labuza and Karel and Schoebel (40, 41) investigated the effect of non-enzymatic browning in freeze-dried systems containing sucrose and organic acids. They reported that food product underwent a rapid non-enzymatic browning even at low relative humidities. The browning was due to reducing sugars produced by acid-catalyzed hydrolysis of sucrose which occurred at below 1% water content.

Negative and Positive Aspects of the Maillard Reaction

The Maillard reaction in foods can have both positive and negative aspects. The negative ones include sugar and amino acid losses or unavailability of lysine; loss of protein nutrative value; and (sometimes) production of undesirable color, aromas, and flavors (42-46). The positive ones comprise the production of desirable color, aroma,

and flavors anti-oxidative properties, and (probably) anti-microbial effects.



Source: Loncin, M., Jacqmain, D., Tutundjlan-Pruvost, A. M., Lenges, J. P. and Blmbenet, J. J.: Influence de leau sur les reactions de Maillard. Acad Sci. 260:3208, 1965.

Figure 3. Dehydration Stages of the Maillard Reaction

The Maillard reaction gives rise to browning in the case of bread crust, cookies, and roasted nuts and other vegetable products. It is capable of producing appetizing aromas and flavors during heating

under very precise conditions. Generally speaking this reaction participates in aroma and flavor development mainly by means of aldehydes formed during the intermediate stage of the Maillard reaction (47).

Wolform, Plunkett, and Cavalier (48) stated that Maillard products formed in the roasting of coffee were a source of flavor and aroma. Newall, Mason, and Matlock (49) indicated that during roasting peanuts, desirable flavor and aroma were produced. Rohan and Stewart (50) showed that the Maillard reaction was involved in the flavor and attraction of chocolate. Also, Agabaynts and Platnow (51) have said that the aroma formation of wine during maderization is the by-product of the Maillard reaction.

Destruction of Amino Acids

Protein and amino acids were reported to react with fats and their oxidation products, polyphenols, various chemical additives, and most of all reducing sugars (52). Maillard reaction in food products seemed to affect the liver, by causing some type of necrosis. A study done on animals with roller dried milk powder showed hepatic necrosis which was in proportion to the heat treatment the milk powder received. The percentage of animals that died due to necrosis of the liver was less than one percent when fed with liquid milk, 40% when fed with spray-dried milk powder, and 76% when fed with roller dried milk powder (53).

A study done by Ferrando (54), parallel to the one above, used meats subjected to varying intensities of heat drying. The more heat dried meats had lowered nutritional efficiencies compared to the less dried meats and the rats fed those meats had a greater incidence of liver hypertrophy. The hypertrophied livers showed the following types

of lesions. There were early necrotic lesions with hemmorohagit symptoms which correspond to mild toxic damage. Ferrando (54) stated that Maillard reaction products developed a state that was compared to undernutrition.

Effect of Maillard Reaction in the Baking of Bread

Role of the Maillard Reaction in Bread Aroma

Bread flavor has been the subject of a great many experiments, justified by the complexity of the phenomena involved: hydration, presence of yeast, kneading, fermentation, baking, and staling. These are responsible for chemical and enzymatic reactions that come to be very important in flavor development (55-57). During fermentation, starch and proteins are partially hydrolyzed into simple sugars and amino acids that can react together during heating, especially in very crisp bread crust or cookies. The Maillard reaction in the outer parts of cereal products is largely responsible for the color and flavor of food products (58-63).

The Maillard reaction is not as intense in crumb that is moderately heated in the wet interior medium as in the outer crust. During baking, free amino acids and free sugars in the crust are drastically reduced, particularly maltose. At the same time carbonyl molecules are 10 times more numerous in the crust than in the crumb. These are furfurals (partially from sugar prolysis) and aldehydes derived from amino acids, as well as numerous nonvolatile compounds. The type and quantity of the substances produced by the Maillard depend on factors such as: sugar

and amino acid concentration in the dough, baking time, or freshness of the bread (63). The addition of even a small amount of free sugars or free amino acids to the dough will considerably increase Maillard reaction intensity in the crust (64).

Bread is an excellent staple supplying many key nutrients. The Maillard browning reaction could significantly reduce the nutritive value of bread when baked or toasted. Bread is prepared from fermented dough mainly of wheat flour. Wheat flour, like other cereal flours is low in lysine. The Maillard browning reaction induced by baking or toasting can aggravate the lysine deficiency and thus reduce the nutritive value of the bread.

Tsen, Reddy, El-samahy (15) found that rats fed conventional bread diet gained less when compared to those fed steam bread or microwave baked bread diet. They also showed that nutritive value of bread as expressed in protein efficiency ratio (PER), was increased significantly if bread was baked with microwave energy or steaming instead of conventional baking. Microwave baking or steaming does not brown the bread crust; accordingly less browning takes place by these processes than conventional baking.

In another study Tsen (15) observed deleterious effect of baking by feeding rats with diets prepared from fermented and proofed dough before and after baking and from bread crust and crumb. PER were found to be less for diets with fermented dough after baking when compared to those values before baking.

Hansen, Johnson, and Ferrel (66) reported that high processing temperatures 108-150° C, and 174° C could cleave some flour protein into peptides, with the production of peptide. Lysine, arginine, and

cystein contents may be susceptible to chemical reduction.

Among all amino acids involved in the browning reaction, lysine with its E-amino group, is especially susceptible to side reaction and cross linking. Thus it is the first to become unavailable. Lysine like other amino acids can also be decomposed by high temperature (26). Other investigators also reported that total lysine content will decrease with baking or toasting.

Antioxidative Properties of Maillard Reaction Product

Lipid oxidation is a major problem in food production and storage. The development of rancid off-flavor limits the storage time for many foods, even when their fat content is low. In fact, when foods are made stable against microbiological deterioration, often lipid oxidation becomes the main deteriorative reaction during storage (67). The formation of Maillard-type reductone-like compounds, characterized as having antioxidative properties, has been described by Hodge and Rist (68). According to Cheftel, Eriksson, and Labuza (47), two classes of MRP have been shown to possess such properties: 1) low molecular weight colorless compounds (Premelanoidins), and 2) higher molecular weight pigmented substances (melanoidins).

The antioxidative effect of MRP in cookies was demonstrated by Lingnert (69). Such an effect was obtained as a consequence of baking the doughs to which sugars and free amino acids had been added previously.

Lingnert and Lundgren (70) incorporated preformed MRP as a sausage ingredient in an effort to improve the oxidative stability of the

product during frozen storage. The development of rancid flavor, as determined by sensory evaluation, was found to be retarded as a consequence of the addition of MRP.

According to Yamaguchi, Koyama, and Fujimaki (71), browning reaction products from sugars and amino acids acted synergistically with tocopherol in preventing oxidation in margarine. These authors further stated that MRP compared favorably with other food antioxidants, such as butylated hydroxyanisole (BHA) and propyl gallate, at the same level of reducing power.

Antimicrobial Properties of MRP

Another desirable aspects of Maillard is its effectiveness as inhibitors of some microbial activities (72-74). It has been postulated that antioxidative properties may partially be responsible for the action. Current information regarding the antimicrobial action is limited to observation in vitro. While an inhibitory effect has been reported in some instances (75), a stimulatory action has been described by others.

Paterson, Rose, and Loeb (76) reported that MRP has no influence on some microorganisms, however, Rosa and Gilliand (77) reported that Maillard reaction products prepared by heating a solution of 0.2 M histidine at 121° C for two hours resulted in a decrease in the growth of microorganisms when non-fat milk was added to the heated solution. They concluded that the general antimicrobial effect MRP is of a bactericide.

Summary of Review of Literature

The Maillard reaction is a set of reactions by which reducing sugars are bound to amino acids (especially lysine) when heated. During this reaction, amino groups of amino acids interact with carboxyl groups of reducing sugars to form glycosylamines by the Amadori rearrangement, which leads to the browning pigmentation (16, 62, 63, 75). Maillard reaction plays an important role in the food industry. Food processing, preservation and storage cause changes in temperature, pH, water activity and composition giving rise to the formation of Maillard compounds. Peanuts are affected very easily, particularly during roasting, since reducing sugars and protein are present. Some of the positive aspects of Maillard reaction include the formation of appetizing aromas and flavors which are produced in baked products, roasting coffee, cocoa and nuts. Antioxidative properties and antimicrobial action are very important attributes from a food preservation standpoint. The use of a food additive which serves a dual function would also be attractive in the food industry.

CHAPTER III

METHOD AND PROCEDURES

A review of related literature indicated the need for further study of the effects of the Maillard reaction on the nutritive value of a food product. As a result, this study was developed to determine the effect of non-enzymatic browning of bread prepared with sucrose or fructose on lysine availability by measuring growth rate of chicks. The research design, attribute selection, data collection, instrumentation and data analyses will be outlined in this chapter.

Research Design

This study was done to test whether incorporating different sugars (fructose or sucrose) into bread and the degree of browning of the bread would affect nutritive quality and, consequently, growth rate of chicks. The different types of bread were prepared in the food research laboratory in Home Economics East building, and chick growth studies were conducted at the Oklahoma State University poultry farm. Both bread preparation and the feeding study were done under controlled conditions.

The two different sugars and the degree of browning of feed were the independent variables and the dependent variable of this study was the chick weight gains, with the treatment assigned to complete randomized design.

Attribute Selection

The research project, to determine whether non-enzymatic browning of feed affected growth rate of chicks, was funded by the College of Home Economics, Oklahoma State University. The experimental unit sample for this study included 320 seven-day-old male chicks, each weighing between 100g and 170g. Eight chicks were randomly assigned to each pen, and five pens were allotted to each of eight treatments in an eight-day feeding trial.

The room had constant incandescent light, and it was equipped with automatic heating and cooling system. Water and feed were provided continuously.

Preliminary Bread Dough Procedure

The bread ingredients were altered so as to provide a complete ration for the chicks, so a bread making procedure was adapted from the basic bread recipe used in previous trials (5). The amount of water was determined by testing different levels of water added to dry ingredients to obtain the proper doughy texture; and optimum kneading, rising, and baking time. The composition of feed is shown in Table I.

Feed Preparation

Two feeds each with a different sugar were prepared. The sugar (sucrose or fructose) were combined with flour, egg solids, cottonseed oil, and yeast. The mixture was mixed thoroughly using a Hobart mixer. Some of the dry feed was reserved as control. The rest was combined with water (800ml) to form bread doughs which were allowed to ferment for 40 minutes at 80°F (26° C), formed into loaves in a greased pan,

proofed for 40 minutes, and baked at 325°F (162° C) for 40 minutes in a commercial deck oven. Following baking the bread loaves were immediately removed from the pans onto racks to facilitate rapid cooling. After the loaves were cooled, they were sliced as follows: 1/4" crust, 1/2" middle, 1/2" whole loaf.

TABLE I

COMPOSITION OF FEED

Ingredients	Grams/100g Dry Ingredients
Dried whole eggs	26.4
Enriched white bread flour	47.8
Sugar[a]	10.0
Baking yeast	5.0
Cottonseed oil	5.0
Mineral mix	5.4
Vitamin mix	0.4
Total dry ingredient weight (g)	100.0
Water (ml/100g ingredients)	800

[a]Sugars used
Sucrose - Dry crystalline sucrose
Fructose - Dry crystalline fructose

Each portion (crust, middle, whole loaf) was dried in a dehydrator at (85°F), ground in a Wiley Mill grinder, and mixed with appropriate amount of vitamin-mineral supplement. The feed was stored in a cool room at approximately 65°F (18° C).

Sucrose (TV brand, Fleming Company, Oklahoma City) was purchased from a local grocery. All-purpose flour (Climax brand, Shawnee Mill, Shawnee, Oklahoma) was used. Yeast, egg solids, and cottonseed oil were ordered from Scrivner Company in Oklahoma City. The vitamin and mineral composition is included in Appendix D.

Assigning Treatment to Pens

Five 10 pen batteries were used for the eight-day growing trial. The pen placement and treatments within the batteries can be seen in Appendix C. The eight treatments were randomly assigned to the pens, and each treatment was replicated five times. The treatments were:

1. Fructose unbaked (FU)
2. Fructose middle (FM)
3. Fructose whole loaf (FW)
4. Fructose crust (FC)
5. Sucrose unbaked (SU)
6. Sucrose middle (SM)
7. Sucrose whole loaf (SW)
8. Sucrose crust (SC)

Random numbers were chosen using a random number table to match the pens with the treatments.

Chicks were individually weighed, wing banded, and randomly assigned to the pens. Five pens were used for each treatment, and each pen contained eight chicks.

Data Collection

Growth rates of chicks fed the treatment rations were measured by

recording the chick weight on days 1, 3, and 8. Since the pen was the experimental unit, feed consumption was recorded per pen daily. Twelve hundred grams of ration were placed in the feeders at the beginning of the experiment. The feeders were weighed daily and their weight brought back to their original amount by addition of the appropriate ration. This added amount, the daily feed consumption, was divided by 8 for a mean per chick's value. Feeds were reweighed at the same time each day (9:00-10:00 a.m.).

Instrumentation

Amino Acid Analysis

A Beckman Automatic Amino Acid Analyzer 121B (Beckman Instruments, Inc., Spino Division, Palo Alto, California, USA) was used to determine the amino acid contents of the feed samples from the different treatments by the method of Walker, Maxwell, Owens, and Buchanan (78). These analyses were done in the Animal Science Department.

Glucometer Reflectance Photometer

Glucose formation (hydrolysis of sucrose) during a model fermentation was monitored using Dextrostix (glucose oxidase reagent strips) and the Glucometer Reflectance Photometer, both products of the Ames Company, a division of Miles Laboratory.

In the model system experimental feed ratio of sugar to yeast was measured (sugar, 10%; yeast, 5%), and luke warm water (110°F) was added. The glucose formed in the fermentation process was measured every 10 minutes for 40 minutes.

Data Analysis

Analyses of data were made by (SAS) (79), with data subjected to an F-test following analysis of variance (ANOVA). Significant differences ($p = .05$) between means for daily gains and daily feed intake were determined using Duncan's multiple range ($p = .05$) to identify where the differences occurred.

CHAPTER IV

RESULTS AND DISCUSSION

This research project was undertaken to explore the effect of feeding breads prepared with two different sugars (sucrose and fructose) on the growth rate of chicks. The hypotheses were tested using analysis variance, followed by F-tests and Duncan's multiple range tests. Level of significance for this study is $p = .05$. (The result of ANOVA can be seen in Appendix B.)

Growth Data

In chicks fed bread with either sucrose or fructose mean daily weight gains were highest in chicks fed unbaked diets (sucrose, 11.16g; fructose, 12.79g). These values were followed by mean weight gains of chicks fed middles (sucrose, 2.25g; fructose, 6.39g); whole loaves (sucrose, 2.14g; fructose, 2.75g); and crust (sucrose, 0.62g; fructose, 0.725g). There were no significant weight differences between chicks fed either unbaked ration, however, chicks fed fructose middle rations gained significantly less than those fed unbaked rations but gained more than those fed fructose whole loaf, sucrose middle, sucrose whole loaf, fructose crust, and sucrose crust. These results are shown in Table II.

Although chicks fed fructose whole loaf, sucrose middle, or sucrose whole loaf gained more than those fed fructose crust or sucrose crust; these results were not significantly different (Figure 4).

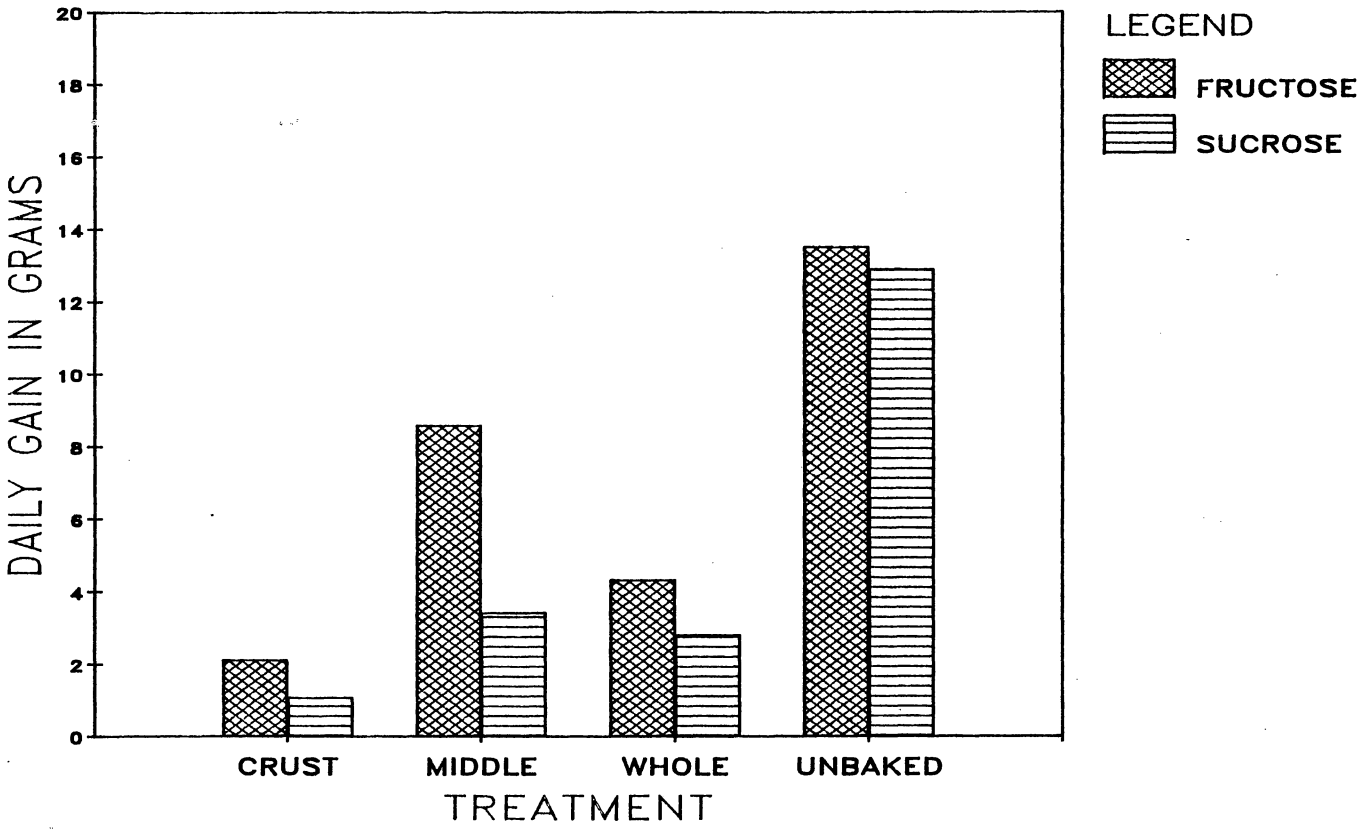


Figure 4. Average Daily Gain of Chicks

TABLE II

DUNCAN'S MULTIPLE RANGE TEST OF
DAILY WEIGHT GAIN OF CHICKS

Treatments	N	Mean (g)	Significance Grouping ($p<.05$)
Fructose unbaked	40	12.8	A
Sucrose unbaked	40	11.1	A
Fructose middle	40	6.4	B
Fructose wholeloaf	40	2.7	C
Sucrose middle	40	2.2	C
Sucrose wholeloaf	40	2.1	C
Fructose crust	40	0.7	C
Sucrose crust	40	0.6	C

Average Weight Gain

The average weight gain of chicks was determined on days 1, 3, and 8. The average daily weight gain was calculated to determine the effect of each treatment on the gain of chicks for all three time intervals.

Feed Intake

Mean feed intake of chicks fed unbaked ration with either sugar were significantly higher than those fed baked rations. However, there was no significant difference between chicks fed sucrose unbaked and fructose unbaked. Feed intakes of chicks fed fructose middle were significantly lower than those fed fructose unbaked or sucrose unbaked but greater than these feeds: fructose whole loaf, sucrose middle, sucrose whole loaf, fructose crust, and sucrose crust. There were no significant differences in feed intakes of chicks fed fructose unbaked

(11.79gms), sucrose middle (13.67gms), sucrose whole loaf (12.84gms), or fructose crust (11.80gms). However, chicks fed sucrose crust (11.07g) consumed less than the unbrowned feeds, fructose middle, or fructose whole loaf. The Duncan's multiple range test of feed intake shown on Table III gives the mean daily feed intakes and the significant differences among the means. Figure 5 indicates the average daily feed intake.

TABLE III

DUNCAN'S MULTIPLE RANGE TEST FEED INTAKE

Treatments	N	Mean (g)	Significance Grouping ($p<.05$)	
Sucrose unbaked	40	36.8	A	
Fructose unbaked	40	36.4	A	
Fructose middle	40	20.6	B	
Fructose wholeloaf	40	14.7	C	
Sucrose middle	40	13.6	C	D
Sucrose wholeloaf	40	12.8	C	D
Fructose crust	40	11.8	C	D
Sucrose crust	40	11.0		D

Lysine Content of Feed

For both sugars, average lysine contents of feeds were highest unbaked (fructose, .81g/100g; sucrose, .87g/100g) followed by middle (fructose, .67g/100g; sucrose, .65g/100g), whole loaf (fructose, .59g/100g; sucrose, .55g/100g); and the crust portion (fructose, .50g/100g; sucrose, .46g/100g) contained the least amount of lysine among

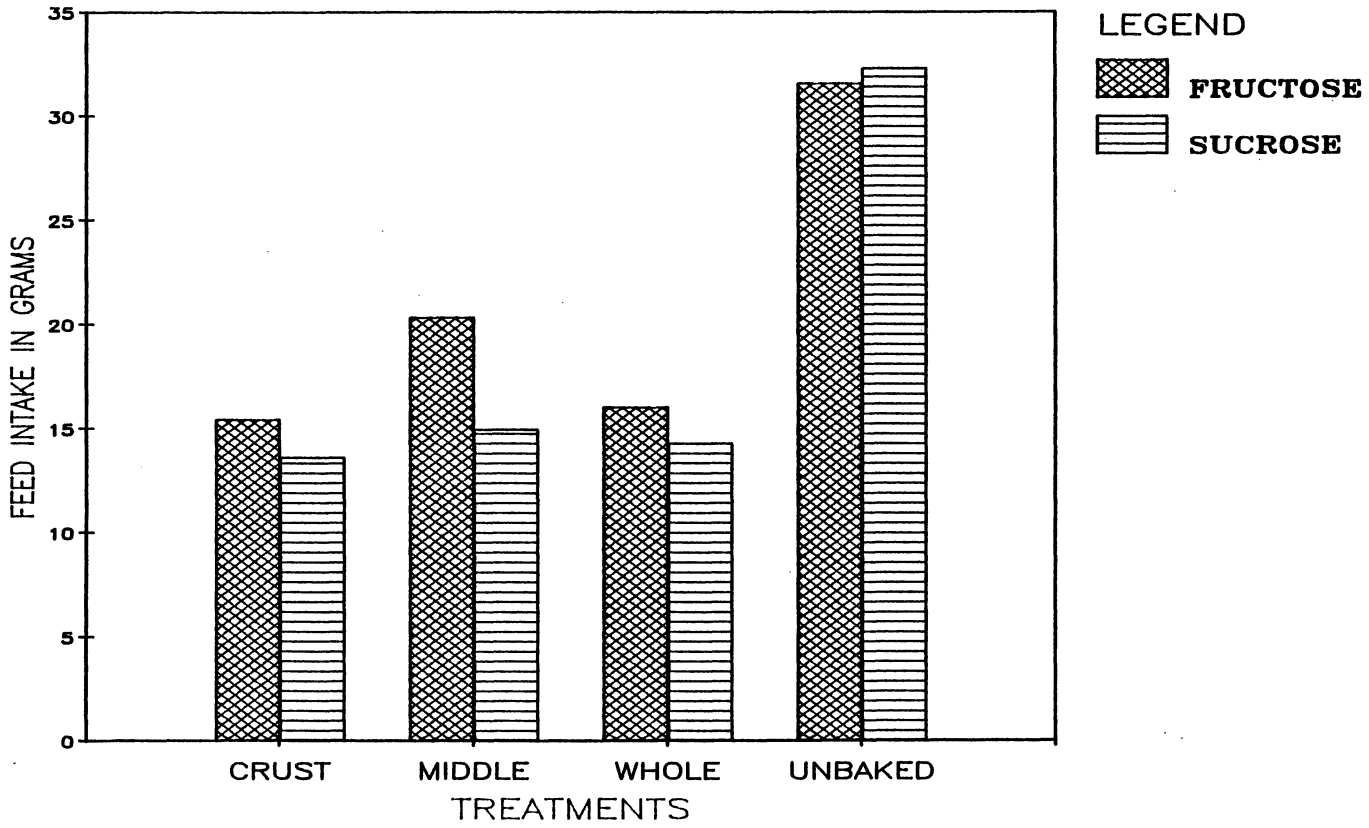


Figure 5. Average Daily Feed Intake of Chicks

all feeds. Further, except for the unbaked feeds, fructose-containing feeds had more lysine than sucrose containing feeds. All of the unbaked feeds had more lysine than the browned feeds. Table IV shows the average lysine content of the feeds. (See Figure 6.)

TABLE IV

MEAN LYSINE CONTENT OF THE FEEDS

Treatments	Mean Lysine Content G/100gms
Fructose unbaked	0.81
Fructose middle	0.67
Fructose whole loaf	0.59
Fructose crust	0.50
Sucrose unbaked	0.87
Sucrose middle	0.65
Sucrose whole loaf	0.55
Sucrose crust	0.46

The lysine contents of the feeds tended to correspond to the chick daily weight gains and feed intake. The feed intake results showed that the chicks consumed more of the unbaked feeds than the browned feeds; thus the chicks that grew less ate less feeds.

A similar result was observed in the studys done by Knight, Hanson, and Teeter (5). When they added lysine to the browned feed, the chicks started to eat again and gained weight. Therefore, it appeared that the loss of available lysine due to baking (browning)

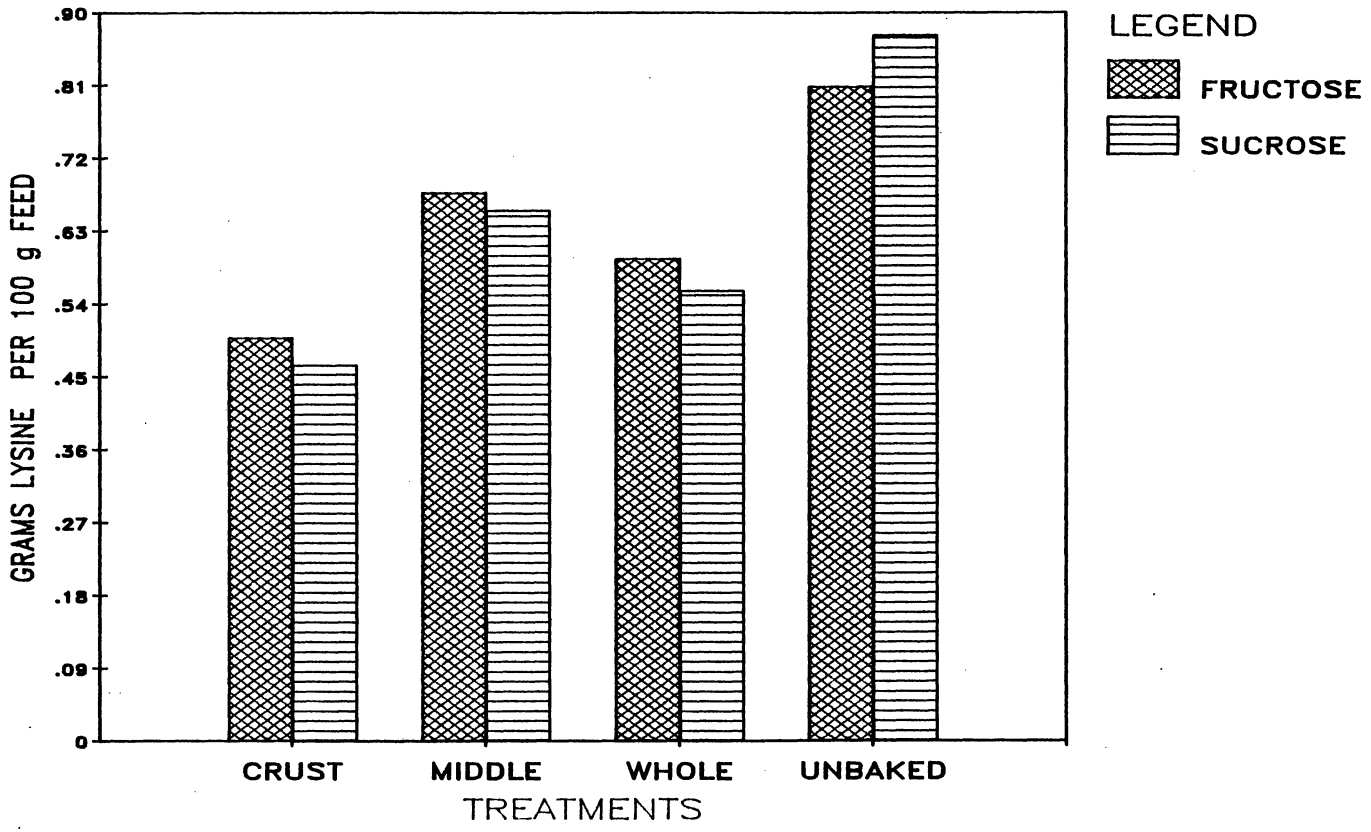


Figure 6. Lysine Content of Chick Feeds

resulted in the reduction in feed consumption and the growth retardation of chicks.

Feed Intake and Growth Response

The weight gain of chicks on the browned feed were in proportion to the amount of feed consumed by these chicks. As can be seen in Tables V and VI, the chicks on the sucrose containing crust diet consumed less and gained less weight than chicks fed the unbrowned feeds, fructose middle, and fructose whole loaf. Chicks fed unbaked rations with either sugar ate the most and tended to gain the most weight among all treatments. The feed efficiencies calculated by feed intake divided by weight gain of the different treatments are shown in Table V. A picture of the different feeds is shown in Figure 7.

TABLE V

FEED EFFICIENCY

Treatments	Average Daily Feed Intake (gms)	Average Daily Weight Gain (gms)	Feed Efficiency
Fructose unbaked	36.5	12.8	2.8
Fructose middle	20.7	6.4	3.2
Fructose whole loaf	14.8	2.7	5.4
Fructose crust	11.8	0.7	16.2
Sucrose unbaked	36.8	11.1	3.3
Sucrose middle	13.6	2.2	6.7
Sucrose whole loaf	12.8	2.1	6.0
Sucrose crust	11.0	0.62	17.8

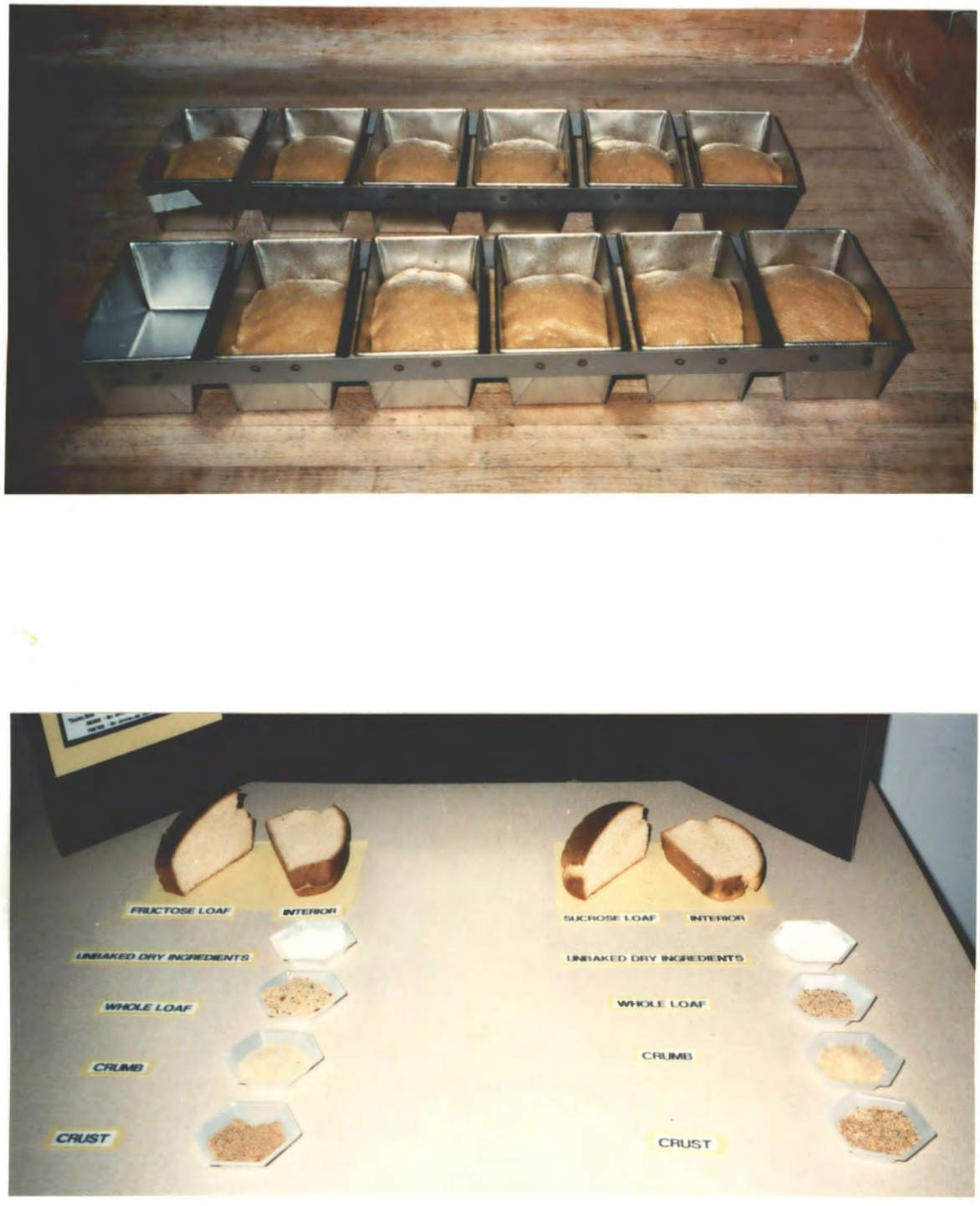


Figure 7. Treatments Prepared from Loaves of Bread Made with Either Sucrose or Fructose

Comparison of Feed Intake, Growth Response and Lysine Content of the Feed

The feed intake and growth responses of chicks compared with the lysine content of feeds are shown in Table VI. In this table, mean daily chick weight gains and feed intakes for the treatments are contrasted with the lysine content of the feeds. (The results of the amino acid analyses done in duplicate are included in Appendix A.)

Sucrose containing feed was the most nutrient binding. This was surprising since sucrose is a non-reducing sugar. However, glucose tests of the dough during fermentation and proofing indicated that the sucrose was largely hydrolyzed prior to baking and that the sugar actually present during heating was a mixture of glucose and fructose, both reducing sugars.

TABLE VI

COMPARISON OF MEAN WEIGHT GAIN OF CHICKS, MEAN FEED INTAKE OF CHICKS, AND LYSINE CONTENT OF THE FEEDS

Treatments	Mean Weight Gain of Chicks (gms)	Mean Feed Intake of Chicks (gms)	Lysine Content of Feeds (g/100gms)
Fructose unbaked	12.8	36.5	0.81
Fructose middle	6.4	20.7	0.67
Fructose whole loaf	2.7	14.8	0.59
Fructose crust	0.72	11.8	0.50
Sucrose unbaked	11.1	36.83	0.87
Sucrose middle	2.2	13.67	0.65
Sucrose whole loaf	2.1	12.84	0.55
Sucrose crust	0.62	11.07	0.46

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The Maillard reaction and its products can induce both positive and negative effects in foods. The negative ones include discoloration, production of undesirable flavors, and loss of available amino acids. The positive aspects are production of desirable color, flavor, and antioxidant properties. These products may also be effective as inhibitors of microbial growth (40, 41, 43-45, 73-75).

The purpose of this study was to investigate the effect of the non-enzymatic browning reaction on growth rate of chicks fed eight different rations which were prepared with two types of sugars. The two sugars used were sucrose and fructose.

The eight treatment feeds were prepared thusly; each of the sugars was combined with the appropriate amount of flour, egg solids, oil, and yeast to make complete chick ration. Some of the dry feed was reserved as a control. The balance was combined with water to form bread doughs which were allowed to ferment for 40 minutes, formed into loaves, proofed for 40 minutes, and baked at 325°F (162° C) for 40 minutes. On two-thirds of the loaves, crusts were removed by trimming away the outer one-fourth inch. Each portion (crust, middle, or whole loaf) was dried, ground and mixed with vitamin and mineral supplements, then stored at 65°F (18° C).

Three hundred twenty 7-day-old male chicks were used in the 8-day feeding trial. After the chicks were individually weighed, eight chicks were randomly assigned to each pen (experimental unit), and five pens were allotted to each of the eight treatments, using a completely randomized design.

Feed and water were provided ad libitum. The feed consumption was recorded daily, and the chicks were weighed on day one, three, and eight of the 8-day growing trial. Feed consumption was determined and recorded daily.

Summary

Based on this study, the following summary could be deduced.

1. The fructose middle feed produced gains significantly less than the unbrowned but greater than the other treatments. Although the browned crusts produced much smaller gains than the whole loaf and sucrose middle, these differences were not significant at the level $p = .05$. Table V shows daily weight gain of chicks. There were no significant differences in mean daily weight gains between chicks when fed either the unbaked fructose or sucrose containing ration.

2. Mean feed intake of chicks fed unbaked rations with either sugar were significantly higher ($p = .05$) than those fed baked rations. Chicks fed sucrose crusts ate the least. However, there were no significant differences between chicks fed sucrose or fructose. This intake data is shown in Table VI.

3. The lysine content of the browned feeds for both of the sugars were less than the unbaked (unbrowned) feeds (Table VI), and the lysine content of the feeds was correlated to the weight gain of the chicks ($r = .95$, $n = 8$, $p = .001$).

4. The chicks fed sucrose crust consumed the least amount of feed 11.0g and gained the least weight 0.6g. This feed had the lowest amount of lysine (1.4gms/100gms). This is shown in Table VI.

Conclusions

Chick growth rate was related to browning, and the retarding effect was greatest in the crust. However, nutrient binding was apparent even in the middle of the loaf at normal baking temperature.

Using the statistical analysis system (SAS) (22), data were analyzed by Analysis of Variance, and Duncan's multiple range test with an alpha level $p = .05$. The results are summarized as follows: there were no significant differences in the growth rate of chicks, feed intakes, or lysine contents of unbaked rations. However, there were significant differences in all of these parameters when the feeds were browned. The most significant decrease tended to be in the sucrose-containing feeds. Thus all of the four hypotheses were rejected. However, tests for the presence of glucose during fermentation period tends to indicate that the sucrose was largely hydrolyzed prior to heating. Based on this and the results of the chick feeding trial, it is the opinion of the researcher that the "sucrose" feeds, except for the unfermented dry ingredients, actually contained primarily reducing sugars glucose and fructose, products of the hydrolyzed sucrose.

Recommendations for Further Study

Our daily bread, served in various forms, is one of the most important foods in the world. Thus, it is important and desirable to improve the nutritive value of bread for the well-being of mankind.

Bread is an excellent staple, supplying such key nutrients as carbohydrates, proteins, vitamins and minerals. Therefore, these recommendations are made:

1. The marked change in nutritive values of baked bread in a conventional baking process observed in this study indicated that there was more nutrient binding in normal food preparation than had been predicted. Possible non-enzymatic browning alternatives such as steaming or microwaving of breads should be explored.

2. The study should be repeated using other test animals to see if the response is the same as in chicks.

3. The experiment should be repeated including as treatments wetted feed and wetted fermented feeds to test the effect of water and fermentation.

4. Determination of the actual structure and reactions of the various sugars currently available for food preparation should be made.

5. The apparent hydrolysis of sucrose observed during dough preparation should be further studied, and an experiment should be made testing whether bread dough comprised of more typical levels of both sucrose and yeast would be as rapidly hydrolyzed.

6. Further studies are needed in yeast breads and also in chemically leavened products to determine the conditions that leads to nutritional loss. This is particularly important since enzymatically produced reducing sugars from corn are becoming widely used in baked products.

BIBLIOGRAPHY

1. Mauron, J.: The Maillard reaction in foods: A critical review from the nutritional stand point. Prog Fd Nutr Sci. 5:35, 1981.

2. Erikson, G.: Maillard reaction in food. Prog Fd Nutr Sci. 5:1, 1981.

3. Reynolds, T. M.: Chemistry of non-enzymatic browning I. Adv Food Res. 12:1, 1963.

4. Patton, A. R.: Present status of heat processing damage to protein foods. Nutr Rev. 8:193, 1950.

5. Knight, S., Hanson, C., and Teeter, R.: Protein quality changes with baking. Fed Proc. 4:1523, 1985.

6. Jagannathan, M., and Knight, S.: Effect of non-enzymatic browning of chick feed on the growth rate of chicks: Masters Thesis. Oklahoma State University. 1985.

7. Rosenberg, H. R., and Rohdenburgh, E. L.: The fortification of bread with lysine. J Nutr. 45:593, 1951.

8. Rosenburg, H. R., and Rohdenburgh, E. L.: The fortification of bread with lysine II. The nutritional value of fortified bread. Arch Biochem Biophys. 37:461, 1952.

9. Rosenberg, H. R., Rohdenburgh, E. L., and Baldini, J. T.: The loss of lysine during baking. Arch Biochem Biophys. 49:263, 1954.

10. Clarke, J. K., and Kennedy, B. M.: Availability of lysine in whole wheat bread and selected breakfast cereals. J Food Sci. 27:609, 1962.

11. Ericson, L. E., Larson, S., and Lid, G.: A comparison of the efficiencies of free lysine and of roller dried milk, fish protein and soybean protein for the supplementation of wheat bread. Acta Physiol Scand. 53:85, 1961.

12. Hutchinson, J. B., Moran, T., and Pace, J.: The nutritive value of bread protein intake, the level of protein intake, the level of supplementation with L-lysine and L-threonine and addition of egg and milk proteins. Brit J Nutr. 13:151, 1959.

13. Jansen, G. R., and Ehle, S. R.: Studies on breads supplemented with soy, nonfat dry milk, and lysine I. Physical and organoleptic properties. Food Tech. 101:1439, 1965.

14. Jansen, G. R., Ehle, S. R., and Hansen, N. L.: Studies on the nutritive loss of supplemented lysine in baking II. Loss in water bread and in bread supplemented with moderate amounts of nonfat dry milk. Food Tech. 18:367, 1964.

15. Tsen, C. C., Reddy, K. R. P., and El-Samahy, K. S.: Effect of the Maillard browning reaction on the nutritive value of breads and pizza crusts: In the Maillard Reaction in Foods and Nutrition: Waller, G. R., and Feather, M. S. (eds.), ACS Symposium Series 215, ACS, Washington, D.C., 1983.

16. Fisher, H.: Chick as an assay animal: In Nutrients in Processed Foods: Proteins, Publishing Science Group, Inc., Action, MA, 1974.

17. Lang, K.: Influence of cooking on foodstuffs. World Rev Nutr Dietet. 12:266, 1970.

18. Baum, S. J.: Introduction to organic and biological chemistry. MacMillan Publishing Co., Inc., New York, 1978.

19. Robinson, C. H., and Lawler, M. R.: Normal and therapeutic nutrition. MacMillan Publishing Co., Inc., New York, 1977.

20. Reed, P. B.: Nutrition an applied science. West Publishing Co., St. Paul, MN, 1980.

21. Maillard, L. C.: Condensation des acides amines en presence de la glycine; cycloglycine et polypeptides. Hed Seances Acad Sci. 153:1078, 1911.

22. Waller, G. R., and Feather, M. S. (eds): The Maillard reaction in foods and nutrition, ACS, Symposium Series 215, ACS, Washington, D.C., 1983.

23. Lee, C. M., Chichester, C. O., and Lee, T. C.: Physiological consequences of browned food products. Proc Int Cong Food Sci Technol. 4:587, 1977.

24. Lea, C. H., and Hannan, R. S.: The effect of activity of water, of pH and of temperature on the primary reaction between casein and glucose. Biochem Biophys Acta. 3:313, 1949.

25. Lewis, V. M., and Lea, C. H.: A note on the relative rates of reaction of several reducing sugars and sugar derivatives with casein. Biochem Biophys Acta. 4:532, 1950.

26. Taeufel, K., Iwalsky, H., and Haertel, I.: Uber Beziehungen zwischen Verfarbungsgrad und Minderung der biologischen Wertigkeit bei der Maillard Reaction. Nahrung. 5:242, 1961.

27. Friedman, L., and Kline, O. L.: The amino acid sugar-reaction. J Biol Chem. 184:599, 1950.

28. Maillard, L. C.: Action des acides amines sur les sucres formation des melanoidines par voie methodologique. Acad Sci. 154:66, 1912.

29. Hodge, J. E.: Chemistry of browning reaction in model systems. J Agric Food Chem. 1:928, 1953.

30. Overby, T. L., Fredrickson, K. L., and Frost, D. V.: Inhibition of the amino acid-sugar reaction. J Nutr. 69:322, 1959.

31. Adrian, J., and Favier, J. C.: La reaction de Maillard. I. Etude du comportement de la lysine pure. Ann Nutrit. 15:181, 1961.

32. Patton, A. R., Hill, G. E., and Foreman, M. E.: Amino acid impairment in casein heated with glucose. Science, 107:623, 1948.

33. Greaves, E. O., and Morgan, A. F.: Nutritive value of raw and heated casein with and without added amino acid. Proc Soc Exp Biol Med. 31:506, 1953.

34. Plakas, M. S., Lee, T., Wolke, E. R., and Meade, L. T.: Effect of Maillard browning on protein utilization and plasma amino acid responses by rainbow trout (Salmo gairdreri). J. Nutr. 115:1589, 1985.

35. Willits, C. O., Underwood, J. C., Lento, H. G., Jr., and Riccinti, C.: Browning of sugar solutions. I. Effect of pH and type of amino acid in dilute sugar solutions. Food Res. 23:61, 1978.

36. Adrian, J.: La reaction de Maillard. II. Etude du comportement de six acides amines puns. Ann Nutrit. 17:220, 1963.

37. Hannan, R. S., and Lea, C. H.: The reactivity of the terminal amino groups of lysine in model systems. Biochem biophys Acta. 9:293, 1952.

38. Loncin, M., Jacqmain, D., Tutundjlan-Pruvost, A. M., Lenges, J. P., and Blmbenet, J. J.: Influence de leau sur les reactions de Maillard. Acad Sci. 260:3208, 1965.

39. Schroeder, C. J., Lacobellis, M., Lees, H., and Smith, A. H.: The effect of heat on the nutritive value of milk proteins as influenced by water and fat. J Nutr. 50:351, 1953.

40. Lubuza, T. P., and Karel, M.: Nonenzymatic browning in model system containing sucrose. J Agri Food Chem. 16:717, 1968.

41. Schoebel, T.: Sucrose hydrolysis at limited water concentration. Masters Thesis. Department of Nutrition and Food Science, Massachusetts Institute of Technology, Cambridge. 1968.

42. Zabrodskii, A. G., and Tikhomirova, E. I. The effect of melanoidin substances on malt microflora. Microbiol. 27:124, 1956.

43. McKeen, W. E.: Interaction product of glysine and dextrose toxic to Phytophthora fragariae. Science. 27:124, 1956.

44. Viswanathan, L., and Sarna, P. S.: A growth inhibitor of L. bulgaricus 09. Nature. 180:1370, 1957.

45. Nickerson, J. T., and Ronsivalli, L. J.: Elementary food science. The AVI Publishing Co., Westport, CT, 1978.

46. Mauron, J.: Summary of session on physiological aspect. Prog Fd Nutr Sci. 5:329, 1981.

47. Cheftel, J. C., Eriksson, C. E., and Labuza, T. C.: Summing up technological aspects. Prog Fd Nutr Sci. 5:467, 1978.

48. Wolform, M. L., Plunkett, R. A., and Cavalier, L. F.: Chemical reactions of amino compounds and sugars; Significance of furan derivatives in color formation. J Agric Food Chem. 14:767, 1967.

49. Newell, J. A., Mason, M. E., and Matlock, R. S.: Precursors of typical roasted peanut flavor. J Agric Food Chem. 14:767, 1967.

50. Rohan, T. A., and Stewart, T. J.: The precursors of chocolate aroma. J Food Sci. 31:202, 1966.

51. Agabalyants, G. G., and Platnow, I. B.: Nitrogen and sugar amines as an index in heat treatment of wine. Vinod Vinograd. 21:6, 1961.

52. Hurrel, R. F., and Carpenter, K. J.: The estimation of available lysine in foodstuff after Maillard reaction. Prog Fd Nutr Sci. 5:159, 1981.

53. Fink, K. S., and Ruge, I.: Uber ernabrrnges physiologische veranderungen der milk being rechfischen broken. Znsyufursche. 13:610, 1958.

54. Ferrando, R.: Effect of biological du chauffage de la viande en presence d'heso amine. Acad Sci. 257:1161, 1963.

55. Collyer, D. M.: Bread flavor. Bakers Digest. 38:43, 1964.

56. Bure, J.: Le gout du pain. Ann Nutrit. 19:153, 1965.

57. Johnson, J. A., Rooney, L., and Salem, A.: Chemistry of bread flavor. Adv Chem Ser. 56:153, 1966.

58. Rothe, M., and Thomas, B.: Uber Bildung zusammensetzung und Bestimmung von aromas toffen des Brotes. Nahrung. 3:1, 1959.

59. Rothe, M.: Uber Flurhtige aromastoffe des roggen brotes. Nahrung. 5:131, 1960.

60. Linko, Y. Y., Johnson, J. A., and Miller, B. S.: The origin and fate of certain carbonyl compounds in white bread. Cereal Chem. 39:468, 1962.

61. Linko, Y. Y., and Johnson, J. A.: Changes in amino acids and formation of carbonyl compounds during baking. J Agric Food Chem. 11:150, 1963.

62. Salem, A., Rooney, L. W., and Johnson, J. A.: Studies of the carbonyl compounds produced by sugar-amine acid reaction. II. In the bread system. Cereal Chem. 44:576, 1967.

63. Johnson, J. A., and El-Dash, A. A.: Role of nonvolatile compounds in bread flavor. J Agric Food Chem. 17:740, 1969.

64. Daniels, D. H. G.: Fractionation of aqueous ethanolic extracts from bread. J Sci Food Agric. 22:136, 1971.

65. Haney, H. N.: Browning reaction in baked products. Masters Thesis. Kansas State University, Manhattan. 1952.

66. Hansen, L. P., Johnston, P. H., and Ferrel, R. E.: Protein nutritional quality of foods and feed; Friedman, M. (ed.), The Maillard Reaction in Foods and Nutrition. Marcel Dekker, New York, 1975.

67. Franzke, C., and Lwainsky, H.: Zurantioxydative wirksamkeit der melanoidine. Deat Lebensm Rundscha. 50:251, 1954.

68. Hodge, J. E., and Rist, C. E.: The Amadori rearrangement under new conditions and its significance for nonenzymatic browning reactions. Am Chem Soc. 75:316, 1953.

69. Lingnert, H.: Antioxidative Maillard reaction products. III. Application in cookies. J Food Proc Pres. 4:235, 1980.

70. Lingnert, H., and Lundgren, B.: Antioxidative Maillard reaction products. IV. Application in sausage. J Food Proc Pres. 4:235, 1980.

71. Yamaguchi, N., Koyama, Y., and Fujimak, M.: Fractionation and antioxidative activity of browning reaction products between D-xylose and glycine. Prog Fd Nutr Sci. 5:429, 1981.

72. Einarsson, H. B., Snygg, G., and Eriksson, L. E.: Inhibition of bacterial growth by Maillard reaction products (MRP). J Agr Food Chem. 31:1043, 1983.

73. McKeen, W. E.: Interaction product of glycine and dextrose toxic to Phytophthora fragariae. Science. 123:509, 1956.

74. Zabrodskii, A. G., and Tikyomirova, E. I.: The effect of melanoidin substances on malt microflora. Microbiol. 27:124, 1958.

75. Rogers, D., King, T. E., and Cheldelin, V. H.: Growth stimulation of lactobacillus by D-glucosylglycine. Proc Soc Exp Biol Med. 82:141, 1953.

76. Peterson, R., Rose, D., and Loeb, L.: Influence of the amino acid-dextrose reaction on growth of Bacillus polymyxa. Can J Res. 27:269, 1949.

77. Rosa, L. D., and Gilliland, S.: Growth inhibition of micro-organisms in refrigerated milk by the addition of Maillard reaction products obtained from a glucose-histidine mixture. Masters Thesis. Oklahoma State University, Stillwater. 1983.

78. Walker, R. W., Maxwell, C. V., Owens, F. N., and Buchanan, S. D.: Milk versus soybean protein sources for pigs: I. Effect on performance and digestibility. J Anim Sci. 63:505, 1986.

79. Barr, A. J., Goodnight, J. H., Sall, J. P., and Helwig, J. T.: A user's guide to SAS 76. SAS Institute, Raleigh, NC, 1976.

APPENDICES

APPENDIX A

VALUES OF DIFFERENT AMINO ACIDS IN EACH FEED

?Y MATTER BASIS

?ME OF SAMPLE----------FNIA SU
?MPLE CHROMATOGRAM NUMBER----9
?MPLE ANALYSIS DATE----------6-86
?IGHT OF SAMPLE (IN GRAMS)---.088422895
?MPLE DILUTION (IN MLS)------15
?RCENT NITROGEN----------2.76982675
?RCENT PROTEIN (N X 6.25)----17.3114172

?INO CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
YS	365	.365	61.918	.1735	.2052	5.6893	LYS
IS	148.92	.1489	25.263	.1062	.392	2.4636	HIS
H3	1472.36	1.4724	249.77	.3499	.4254	2.6735	NH3
GP	500	.5	84.82	0	0	0	AGP
RG	301.48	.3015	51.143	.2865	.8909	5.5995	ARG
YS	0	0	0	0	0	0	CYS
SP	554.32	.5543	94.034	.1317	1.2516	7.8665	ASP
HR	304.6	.3046	51.672	.0724	.6155	3.8687	THR
ER	539.68	.5397	91.551	.1282	.9621	6.047	SER
LU	1309.08	1.3091	222.071	.3111	3.2673	20.5358	GLU
RO	515.52	.5155	87.452	.1225	1.0068	6.3282	PRO
LY	436.08	.4361	73.976	.1036	.5554	3.4909	GLY
LA	492.96	.493	83.625	.1171	.745	4.6826	ALA
YS/2	115.6	.1156	19.61	.0275	.2356	1.4809	CYS/2
AL	432.28	.4323	73.332	.1027	.8592	5.3999	VAL
ET	164.68	.1647	27.936	.0391	.4168	2.6199	MET
LE	320.36	.3204	54.346	.0761	.7129	4.4808	ILE
EU	579.56	.5796	98.316	.1377	1.2897	8.1061	LEU
LE	500	.5	84.82	0	0	0	NLE
YR	192.36	.1924	32.632	.0457	.5913	3.7162	TYR
HE	281.08	.2811	47.682	.0668	.7877	4.9506	PHE
TOTALS*				2.3983	15.9104	100	

ECOVERED NITROGEN= 86.5859473%

iS IS BASIS

AME OF SAMPLE----------FNIA SU
AMPLE CHROMATOGRAM NUMBER----9
AMPLE ANALYSIS DATE----------6-86
EIGHT OF SAMPLE (IN GRAMS)---.09515
AMPLE DILUTION (IN MLS)------15
ERCENT NITROGEN--------------2.574
ERCENT PROTEIN (N X 6.25)----16.0875

MINO CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
YS	365	.365	57.541	.1612	.8412	5.6893	LYS
IS	148.92	.1489	23.477	.0987	.3643	2.4636	HIS
H3	1472.36	1.4724	232.111	.3251	.3953	2.6735	NH3
GP	500	.5	78.823	0	0	0	AGP
RG	301.48	.3015	47.527	.2663	.8279	5.5995	ARG
YS	0	0	0	0	0	0	CYS
SP	554.32	.5543	87.386	.1224	1.1631	7.8665	ASP
HR	304.6	.3046	48.019	.0673	.572	3.8687	THR
ER	539.68	.5397	85.078	.1192	.8941	6.047	SER
LU	1309.08	1.3091	206.371	.2891	3.0363	20.5358	GLU
RO	515.52	.5155	81.27	.1138	.9357	6.3282	PRO
LY	436.08	.4361	68.746	.0963	.5161	3.4909	GLY
LA	492.96	.493	77.713	.1089	.6923	4.6826	ALA
YS/2	115.6	.1156	18.224	.0255	.219	1.4809	CYS/2
AL	432.28	.4323	68.147	.0955	.7984	5.3999	VAL
ET	164.68	.1647	25.961	.0364	.3874	2.6199	MET
LE	320.36	.3204	50.503	.0707	.6625	4.4808	ILE
EU	579.56	.5796	91.365	.128	1.1985	8.1061	LEU
LE	500	.5	78.823	0	0	0	NLE
YR	192.36	.1924	30.325	.0425	.5495	3.7162	TYR
HE	281.08	.2811	44.311	.0621	.732	4.9506	PHE
TOTALS*				2.2287	14.7855	100	

ECOVERED NITROGEN= 86.5859473%

)RY MATTER BASIS

NAME OF SAMPLE----------FNIA SM
SAMPLE CHROMATOGRAM NUMBER----7
SAMPLE ANALYSIS DATE----------6-86
WEIGHT OF SAMPLE (IN GRAMS)---.08938795
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------2.79822952
PERCENT PROTEIN (N X 6.25)----17.4889345

AMINO ACID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
LYS	278.16	.2782	46.677	.1308	.6824	4.3801	LYS
HIS	152.32	.1523	25.56	.1074	.3966	2.5457	HIS
NH3	1454.68	1.4547	244.107	.3419	.4157	2.6684	NH3
AGP	500	.5	83.904	0	0	0	AGP
ARG	286.8	.2868	48.127	.2696	.8384	5.3814	ARG
CYS	0	0	0	0	0	0	CYS
ASP	561.64	.5616	94.248	.132	1.2544	8.0521	ASP
THR	311.08	.3111	52.202	.0731	.6218	3.9914	THR
SER	554.44	.5544	93.039	.1303	.9778	6.2761	SER
GLU	1328.4	1.3284	222.916	.3122	3.2798	21.0524	GLU
PRO	535.04	.535	89.784	.1258	1.0337	6.6351	PRO
GLY	442.76	.4428	74.299	.1041	.5578	3.5807	GLY
ALA	518	.518	86.924	.1218	.7744	4.9708	ALA
CYS/2	121.36	.1214	20.365	.0285	.2447	1.5706	CYS/2
VAL	419.84	.4198	70.452	.0987	.8254	5.2983	VAL
MET	127.44	.1274	21.385	.03	.3191	2.0482	MET
ILE	313.72	.3137	52.645	.0737	.6906	4.4328	ILE
LEU	583.88	.5839	97.98	.1372	1.2853	8.2502	LEU
NLE	500	.5	83.904	0	0	0	NLE
TYR	194.8	.1948	32.689	.0458	.5923	3.8018	TYR
PHE	284.6	.2846	47.758	.0669	.7889	5.064	PHE
TOTALS				2.3298	15.5791	100	

RECOVERED NITROGEN= 83.2610398%

S IS BASIS

AME OF SAMPLE----------FNIA SM
AMPLE CHROMATOGRAM NUMBER----7
AMPLE ANALYSIS DATE----------6-86
EIGHT OF SAMPLE (IN GRAMS)---.0965
AMPLE DILUTION (IN MLS)------15
ERCENT NITROGEN----------2.592
ERCENT PROTEIN (N X 6.25)----16.2

MINO CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
YS	278.16	.2782	43.237	.1211	.6321	4.3801	LYS
IS	152.32	.1523	23.677	.0995	.3674	2.5457	HIS
H3	1454.68	1.4547	226.116	.3167	.3851	2.6684	NH3
GP	500	.5	77.72	0	0	0	AGP
RG	286.8	.2868	44.58	.2498	.7766	5.3814	ARG
YS	0	0	0	0	0	0	CYS
SP	561.64	.5616	87.302	.1223	1.162	8.0521	ASP
HR	311.08	.3111	48.354	.0677	.576	3.9914	THR
ER	554.44	.5544	86.182	.1207	.9057	6.2761	SER
LU	1328.4	1.3284	206.487	.2892	3.038	21.0524	GLU
RO	535.04	.535	83.167	.1165	.9575	6.6351	PRO
LY	442.76	.4428	68.823	.0964	.5167	3.5807	GLY
LA	518	.518	80.518	.1128	.7173	4.9708	ALA
YS/2	121.36	.1214	18.864	.0264	.2267	1.5706	CYS/2
AL	419.84	.4198	65.26	.0914	.7646	5.2983	VAL
ET	127.44	.1274	19.809	.0277	.2956	2.0482	MET
LE	313.72	.3137	48.765	.0683	.6397	4.4328	ILE
EU	583.88	.5839	90.759	.1271	1.1906	8.2502	LEU
LE	500	.5	77.72	0	0	0	NLE
YR	194.8	.1948	30.28	.0424	.5486	3.8018	TYR
HE	284.6	.2846	44.238	.062	.7308	5.064	PHE
TOTALS*				2.1581	14.4309	100	

ECOVERED NITROGEN= 83.2610398%

Y MATTER BASIS

ME OF SAMPLE----------FNIA SW
MPLE CHROMATOGRAM NUMBER----3
MPLE ANALYSIS DATE----------6-86
IGHT OF SAMPLE (IN GRAMS)---.08745318
MPLE DILUTION (IN MLS)------15
RCENT NITROGEN----------2.80680703
RCENT PROTEIN (N X 6.25)----17.5425439

INO ID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
S	232.24	.2322	39.834	.1116	.5823	3.7026	LYS
S	144.4	.1444	24.768	.1041	.3843	2.4434	HIS
3	1425.64	1.4256	244.526	.3425	.4164	2.6477	NH3
P	500	.5	85.76	0	0	0	AGP
G	232	.232	39.793	.223	.6932	4.4074	ARG
S	0	0	0	0	0	0	CYS
P	548.36	.5484	94.055	.1317	1.2519	7.9596	ASP
R	315.24	.3152	54.07	.0757	.6441	4.0952	THR
R	563.12	.5631	96.587	.1353	1.015	6.4537	SER
U	1329.52	1.3295	228.04	.3194	3.3551	21.3326	GLU
O	567.8	.5678	97.389	.1364	1.1212	7.1291	PRO
Y	434.36	.4344	74.502	.1044	.5594	3.5565	GLY
A	499.96	.5	85.753	.1201	.764	4.8575	ALA
S/2	110.4	.1104	18.936	.0265	.2275	1.4466	CYS/2
L	423.52	.4235	72.642	.1018	.8511	5.4113	VAL
T	170.6	.1706	29.261	.041	.4366	2.776	MET
E	317.72	.3177	54.495	.0763	.7149	4.5453	ILE
U	581.88	.5819	99.804	.1398	1.3092	8.3243	LEU
E	500	.5	85.76	0	0	0	NLE
R	193	.193	33.103	.0464	.5998	3.8136	TYR
E	282.96	.283	48.533	.068	.8017	5.0975	PHE
*TOTALS***				2.3039	15.7278	100	

COVERED NITROGEN= 82.0834126%

S IS BASIS

AME OF SAMPLE----------FNIA SW
AMPLE CHROMATOGRAM NUMBER----3
AMPLE ANALYSIS DATE----------6-86
EIGHT OF SAMPLE (IN GRAMS)---.0954
AMPLE DILUTION (IN MLS)------15
ERCENT NITROGEN----------2.573
ERCENT PROTEIN (N X 6.25)----16.08125

MINO CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
YS	232.24	.2322	36.516	.1023	.5338	3.7026	LYS
IS	144.4	.1444	22.704	.0954	.3523	2.4434	HIS
H3	1425.64	1.4256	224.157	.314	.3817	2.6477	NH3
GP	500	.5	78.616	0	0	0	ASP
RG	232	.232	36.478	.2044	.6354	4.4074	ARG
YS	0	0	0	0	0	0	CYS
SP	548.36	.5484	86.22	.1208	1.1476	7.9596	ASP
HR	315.24	.3152	49.566	.0694	.5904	4.0952	THR
ER	563.12	.5631	88.541	.124	.9305	6.4537	SER
LU	1329.52	1.3295	209.044	.2928	3.0757	21.3326	GLU
RO	567.8	.5678	89.277	.125	1.0278	7.1291	PRO
LY	434.36	.4344	68.296	.0957	.5128	3.5565	GLY
LA	499.96	.5	78.61	.1101	.7003	4.8575	ALA
YS/2	110.4	.1104	17.358	.0243	.2086	1.4466	CYS/2
AL	423.52	.4235	66.591	.0933	.7802	5.4113	VAL
ET	170.6	.1706	26.824	.0376	.4002	2.776	MET
LE	317.72	.3177	49.956	.07	.6553	4.5453	ILE
EU	581.88	.5819	91.491	.1282	1.2002	8.3243	LEU
LE	500	.5	78.616	0	0	0	NLE
YR	193	.193	30.346	.0425	.5498	3.8136	TYR
HE	282.96	.283	44.491	.0623	.7349	5.0975	PHE
TOTALS*				2.112	14.4177	100	

ECOVERED NITROGEN= 82.0834125%

S IS BASIS

AME OF SAMPLE----------FNIA SC
AMPLE CHROMATOGRAM NUMBER----12
AMPLE ANALYSIS DATE----------6-86
EIGHT OF SAMPLE (IN GRAMS)---.09455
AMPLE DILUTION (IN MLS)------15
ERCENT NITROGEN----------2.744
ERCENT PROTEIN (N X 6.25)----17.15

MINO CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
YS	194.32	.1943	30.828	.0864	.4507	3.1927	LYS
IS	136.56	.1366	21.665	.091	.3361	2.3814	HIS
H3	1421.96	1.422	225.589	.316	.3842	2.7216	NH3
GP	500	.5	79.323	0	0	0	AGP
RG	190.24	.1902	30.181	.1691	.5258	3.7245	ARG
YS	0	0	0	0	0	0	CYS
GP	537.44	.5374	85.263	.1194	1.1348	8.0395	ASP
HR	302.44	.3024	47.981	.0672	.5715	4.049	THR
ER	546.72	.5467	86.735	.1215	.9115	6.4573	SER
LU	1322.24	1.3222	209.768	.2938	3.0863	21.8642	GLU
RO	536.96	.537	85.187	.1193	.9808	6.9479	PRO
LY	443.56	.4436	70.369	.0986	.5283	3.7428	GLY
LA	499.48	.4995	79.241	.111	.706	5.0011	ALA
YS/2	96.28	.0963	15.274	.0214	.1835	1.3001	CYS/2
AL	422.16	.4222	66.974	.0938	.7847	5.5588	VAL
ET	185.24	.1852	29.388	.0412	.4385	3.1064	MET
LE	310.4	.3104	49.244	.069	.646	4.5763	ILE
EU	578.56	.5786	91.786	.1286	1.2041	8.5298	LEU
LE	500	.5	79.323	0	0	0	NLE
YR	185.88	.1859	29.489	.0413	.5343	3.7852	TYR
HE	270.48	.2705	42.911	.0601	.7088	5.0216	PHE
TOTALS*				2.0486	14.1159	100	

ECOVERED NITROGEN= 74.6582424%

)RY MATTER BASIS

)AME OF SAMPLE----------FNIA SC
)AMPLE CHROMATOGRAM NUMBER----12
)AMPLE ANALYSIS DATE----------6-86
)EIGHT OF SAMPLE (IN GRAMS)---.08838534
)AMPLE DILUTION (IN MLS)------15
)ERCENT NITROGEN----------2.93538725
)ERCENT PROTEIN (N X 6.25)----18.3461703

)MINO)CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
.YS	194.32	.1943	32.978	.0924	.4821	3.1927	LYS
)IS	136.56	.1366	23.176	.0974	.3596	2.3814	HIS
)H3	1421.96	1.422	241.323	.338	.411	2.7216	NH3
)GP	500	.5	84.856	0	0	0	AGP
)RG	190.24	.1902	32.286	.1809	.5624	3.7245	ARG
:YS	0	0	0	0	0	0	CYS
)SP	537.44	.5374	91.21	.1278	1.214	8.0395	ASP
)HR	302.44	.3024	51.328	.0719	.6114	4.049	THR
)ER	546.72	.5467	92.785	.13	.9751	6.4573	SER
)LU	1322.24	1.3222	224.399	.3143	3.3016	21.8642	GLU
)RO	536.96	.537	91.128	.1276	1.0492	6.9479	PRO
)LY	443.56	.4436	75.277	.1054	.5652	3.7428	GLY
)LA	499.48	.4995	84.767	.1187	.7552	5.0011	ALA
:YS/2	96.28	.0963	16.34	.0229	.1963	1.3001	CYS/2
)AL	422.16	.4222	71.645	.1004	.8394	5.5588	VAL
)ET	185.24	.1852	31.437	.044	.4691	3.1064	MET
LE	310.4	.3104	52.678	.0738	.691	4.5763	ILE
.EU	578.56	.5786	98.188	.1375	1.288	8.5298	LEU
)LE	500	.5	84.856	0	0	0	NLE
:YR	185.88	.1859	31.546	.0442	.5716	3.7852	TYR
)HE	270.48	.2705	45.904	.0643	.7583	5.0216	PHE
:**TOTALS***				2.1915	15.1004	100	

.ECOVERED NITROGEN= 74.6582424%

)RY MATTER BASIS

NAME OF SAMPLE----------FNIA FU
SAMPLE CHROMATOGRAM NUMBER----4
SAMPLE ANALYSIS DATE----------6-86
WEIGHT OF SAMPLE (IN GRAMS)---.08920573
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------2.73323137
PERCENT PROTEIN (N X 6.25)----17.0826961

AMINO ACID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
LYS	344.16	.3442	57.871	.1621	.846	5.521	LYS
HIS	142.92	.1429	24.032	.101	.3729	2.4334	HIS
NH3	1460.2	1.4602	245.534	.3439	.4181	2.7288	NH3
AGP	500	.5	84.075	0	0	0	AGP
ARG	286.84	.2868	48.232	.2702	.8402	5.4831	ARG
CYS	0	0	0	0	0	0	CYS
ASP	494.24	.4942	83.107	.1164	1.1062	7.2186	ASP
THR	280.08	.2801	47.096	.066	.561	3.661	THR
SER	499.6	.4996	84.008	.1177	.8828	5.7613	SER
GLU	1314	1.314	220.95	.3095	3.2508	21.2146	GLU
PRO	537.64	.5376	90.405	.1266	1.0408	6.7923	PRO
GLY	424.88	.4249	71.444	.1001	.5364	3.5005	GLY
ALA	472	.472	79.367	.1112	.7071	4.6143	ALA
CYS/2	120.8	.1208	20.313	.0285	.2441	1.5927	CYS/2
VAL	415.68	.4157	69.897	.0979	.8189	5.3441	VAL
MET	174.16	.1742	29.285	.041	.437	2.8516	MET
ILE	312.16	.3122	52.49	.0735	.6886	4.4935	ILE
LEU	561.76	.5618	94.46	.1323	1.2391	8.0864	LEU
NLE	500	.5	84.075	0	0	0	NLE
TYR	188.96	.189	31.774	.0445	.5757	3.757	TYR
PHE	272.84	.2728	45.878	.0643	.7579	4.9457	PHE
TOTALS				2.3066	15.3236	100	

RECOVERED NITROGEN= 84.3921353%

AS IS BASIS

NAME OF SAMPLE----------FNIA FU
SAMPLE CHROMATOGRAM NUMBER----4
SAMPLE ANALYSIS DATE----------6-86
WEIGHT OF SAMPLE (IN GRAMS)---.09745
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------2.502
PERCENT PROTEIN (N X 6.25)----15.6375

AMINO ACID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
LYS	344.16	.3442	52.975	.1484	.7744	5.521	LYS
HIS	142.92	.1429	21.999	.0924	.3413	2.4334	HIS
NH3	1460.2	1.4602	224.761	.3148	.3828	2.7288	NH3
AGP	500	.5	76.963	0	0	0	AGP
ARG	286.84	.2868	44.152	.2474	.7691	5.4831	ARG
CYS	0	0	0	0	0	0	CYS
ASP	494.24	.4942	76.076	.1066	1.0126	7.2186	ASP
THR	280.08	.2801	43.111	.0604	.5135	3.661	THR
SER	499.6	.4996	76.901	.1077	.8082	5.7613	SER
GLU	1314	1.314	202.258	.2833	2.9758	21.2146	GLU
PRO	537.64	.5376	82.756	.1159	.9528	6.7923	PRO
GLY	424.88	.4249	65.4	.0916	.491	3.5005	GLY
ALA	472	.472	72.653	.1018	.6473	4.6143	ALA
CYS/2	120.8	.1208	18.594	.026	.2234	1.5927	CYS/2
VAL	415.68	.4157	63.984	.0896	.7496	5.3441	VAL
MET	174.16	.1742	26.808	.0375	.4	2.8516	MET
ILE	312.16	.3122	48.049	.0673	.6303	4.4935	ILE
LEU	561.76	.5618	86.469	.1211	1.1343	8.0864	LEU
NLE	500	.5	76.963	0	0	0	NLE
TYR	188.96	.189	29.086	.0407	.527	3.757	TYR
PHE	272.84	.2728	41.997	.0588	.6937	4.9457	PHE
TOTALS*				2.1115	14.0272	100	

RECOVERED NITROGEN= 84.3921354%

S IS BASIS

AME OF SAMPLE----------FNIA EM
AMPLE CHROMATOGRAM NUMBER----6
AMPLE ANALYSIS DATE----------6-86
EIGHT OF SAMPLE (IN GRAMS)---.099
AMPLE DILUTION (IN MLS)------15
ERCENT NITROGEN----------2.547
ERCENT PROTEIN (N X 6.25)----15.91875

MINO CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
YS	297.2	.2972	45.03	.1261	.6583	4.5837	LYS
IS	148	.148	22.424	.0942	.3479	2.4227	HIS
H3	1457.76	1.4578	220.873	.3094	.3761	2.6191	NH3
GP	500	.5	75.758	0	0	0	AGP
RG	287.92	.2879	43.624	.2444	.7599	5.2914	ARG
YS	0	0	0	0	0	0	CYS
SP	534.96	.535	81.055	.1135	1.0788	7.512	ASP
HR	305.4	.3054	46.273	.0648	.5512	3.838	THR
ER	545.28	.5453	82.618	.1157	.8682	6.0455	SER
LU	1367.6	1.3676	207.212	.2902	3.0487	21.2282	GLU
RO	560.4	.5604	84.909	.1189	.9776	6.8068	PRO
LY	453.92	.4539	68.776	.0963	.5164	3.5955	GLY
LA	529.44	.5294	80.218	.1124	.7147	4.9762	ALA
YS/2	118.48	.1185	17.952	.0251	.2157	1.5018	CYS/2
AL	448.12	.4481	67.897	.0951	.7955	5.539	VAL
ET	139.6	.1396	21.152	.0296	.3156	2.1975	MET
LE	330.24	.3302	50.036	.0701	.6564	4.5704	ILE
EU	602.6	.6026	91.303	.1279	1.1977	8.3397	LEU
LE	500	.5	75.758	0	0	0	NLE
YR	200.12	.2001	30.321	.0425	.5494	3.8254	TYR
HE	293.04	.293	44.4	.0622	.7334	5.107	PHE
TOTALS*				2.1386	14.3616	100	

ECOVERED NITROGEN= 83.9662356%

RY MATTER BASIS

ME OF SAMPLE----------FNIA FM
MPLE CHROMATOGRAM NUMBER----6
MPLE ANALYSIS DATE----------6-86
EIGHT OF SAMPLE (IN GRAMS)---.093159
MPLE DILUTION (IN MLS)------15
ERCENT NITROGEN----------2.70669501
ERCENT PROTEIN (N X 6.25)----16.9168438

MINO CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
YS	297.2	.2972	47.854	.1341	.6996	4.5837	LYS
IS	148	.148	23.83	.1001	.3697	2.4227	HIS
H3	1457.76	1.4578	234.721	.3288	.3997	2.6191	NH3
GP	500	.5	80.508	0	0	0	AGP
RG	287.92	.2879	46.359	.2597	.8076	5.2914	ARG
YS	0	0	0	0	0	0	CYS
SP	534.96	.535	86.137	.1207	1.1465	7.512	ASP
HR	305.4	.3054	49.174	.0689	.5858	3.838	THR
ER	545.28	.5453	87.798	.123	.9227	6.0455	SER
LU	1367.6	1.3676	220.204	.3084	3.2399	21.2282	GLU
RO	560.4	.5604	90.233	.1264	1.0389	6.8068	PRO
LY	453.92	.4539	73.088	.1024	.5487	3.5955	GLY
LA	529.44	.5294	85.248	.1194	.7595	4.9762	ALA
YS/2	118.48	.1185	19.077	.0267	.2292	1.5018	CYS/2
AL	448.12	.4481	72.154	.1011	.8454	5.539	VAL
ET	139.6	.1396	22.478	.0315	.3354	2.1975	MET
LE	330.24	.3302	53.174	.0745	.6975	4.5704	ILE
EU	602.6	.6026	97.028	.1359	1.2728	8.3397	LEU
LE	500	.5	80.508	0	0	0	NLE
YR	200.12	.2001	32.222	.0451	.5838	3.8254	TYR
HE	293.04	.293	47.184	.0661	.7794	5.107	PHE
TOTALS*				2.2727	15.262	100	

ECOVERED NITROGEN= 83.9662356%

\S IS BASIS

\AME OF SAMPLE----------FNIA FW
SAMPLE CHROMATOGRAM NUMBER----11
SAMPLE ANALYSIS DATE----------6-86
\EIGHT OF SAMPLE (IN GRAMS)---.08975
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------2.637
PERCENT PROTEIN (N X 6.25)----16.48125

\MINO \CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
LYS	232.72	.2327	38.895	.109	.5686	3.9319	LYS
HIS	136.32	.1363	22.783	.0957	.3535	2.4445	HIS
NH3	1447.44	1.4474	241.912	.3388	.412	2.8488	NH3
AGP	500	.5	83.565	0	0	0	AGP
ARG	232.4	.2324	38.841	.2176	.6766	4.6788	ARG
CYS	0	0	0	0	0	0	CYS
ASP	497.76	.4978	83.191	.1165	1.1073	7.6569	ASP
THR	277.64	.2776	46.402	.065	.5527	3.8223	THR
SER	501.24	.5012	83.773	.1173	.8804	6.0878	SER
GLU	1257.72	1.2577	210.204	.2944	3.0927	21.3865	GLU
PRO	506.88	.5069	84.715	.1187	.9753	6.7445	PRO
GLY	412.48	.4125	68.938	.0966	.5176	3.5792	GLY
ALA	475.88	.4759	79.534	.1114	.7086	4.8998	ALA
CYS/2	96.56	.0966	16.138	.0226	.1939	1.3408	CYS/2
VAL	406.88	.4069	68.002	.0953	.7967	5.5093	VAL
MET	175.16	.1752	29.275	.041	.4368	3.0206	MET
ILE	309	.309	51.643	.0723	.6775	4.6847	ILE
LEU	556.36	.5564	92.985	.1302	1.2198	8.4349	LEU
NLE	500	.5	83.565	0	0	0	NLE
TYR	183.36	.1834	30.645	.0429	.5553	3.8397	TYR
PHE	266.56	.2666	44.55	.0624	.7359	5.089	PHE
TOTALS*				2.1478	14.4611	100	

ECOVERED NITROGEN= 81.4504586%

RY MATTER BASIS

NME OF SAMPLE----------FNIA EW
MPLE CHROMATOGRAM NUMBER----11
MPLE ANALYSIS DATE----------6-86
EIGHT OF SAMPLE (IN GRAMS)---.081358375
MPLE DILUTION (IN MLS)------15
ERCENT NITROGEN----------2.90899062
ERCENT PROTEIN (N X 6.25)----18.1811914

MINO CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
YS	232.72	.2327	42.906	.1202	.6272	3.9319	LYS
IS	136.32	.1363	25.133	.1056	.39	2.4445	HIS
H3	1447.44	1.4474	266.864	.3738	.4545	2.8488	NH3
3P	500	.5	92.185	0	0	0	AGP
RG	232.4	.2324	42.847	.2401	.7464	4.6788	ARG
YS	0	0	0	0	0	0	CYS
SP	497.76	.4978	91.772	.1285	1.2215	7.6569	ASP
HR	277.64	.2776	51.188	.0717	.6098	3.8223	THR
ER	501.24	.5012	92.413	.1294	.9712	6.0878	SER
LU	1257.72	1.2577	231.885	.3248	3.4117	21.3865	GLU
RO	506.88	.5069	93.453	.1309	1.0759	6.7445	PRO
LY	412.48	.4125	76.049	.1065	.571	3.5792	GLY
LA	475.88	.4759	87.738	.1229	.7817	4.8998	ALA
YS/2	96.56	.0966	17.803	.0249	.2139	1.3408	CYS/2
AL	406.88	.4069	75.016	.1051	.8789	5.5093	VAL
ET	175.16	.1752	32.294	.0452	.4819	3.0206	MET
LE	309	.309	56.97	.0798	.7473	4.6847	ILE
EU	556.36	.5564	102.576	.1437	1.3456	8.4349	LEU
LE	500	.5	92.185	0	0	0	NLE
YR	183.36	.1834	33.806	.0474	.6125	3.8397	TYR
HE	266.56	.2666	49.146	.0688	.8118	5.089	PHE
TOTALS*				2.3694	15.9527	100	

ECOVERED NITROGEN= 81.4504586%

3 IS BASIS

NME OF SAMPLE----------FNIA FC
AMPLE CHROMATOGRAM NUMBER----13
AMPLE ANALYSIS DATE----------6-86
EIGHT OF SAMPLE (IN GRAMS)---.0944
AMPLE DILUTION (IN MLS)------15
ERCENT NITROGEN----------2.573
ERCENT PROTEIN (N X 6.25)----16.08125

MINO CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
YS	205.72	.2057	32.689	.0916	.4779	3.2884	LYS
IS	142.68	.1427	22.672	.0953	.3518	2.4207	HIS
H3	1562.8	1.5628	248.326	.3478	.4229	2.9101	NH3
GP	500	.5	79.449	0	0	0	AGP
RG	200.16	.2002	31.805	.1782	.554	3.8126	ARG
YS	0	0	0	0	0	0	CYS
SP	531.12	.5311	84.394	.1182	1.1233	7.7297	ASP
HR	299.96	.3	47.663	.0668	.5678	3.907	THR
ER	534.8	.5348	84.979	.119	.893	6.1453	SER
LU	1348.44	1.3484	214.265	.3001	3.1525	21.6933	GLU
RO	557.6	.5576	88.602	.1241	1.0201	7.0195	PRO
LY	453.44	.4534	72.051	.1009	.541	3.7225	GLY
LA	514	.514	81.674	.1144	.7276	5.0071	ALA
YS/2	100.52	.1005	15.972	.0224	.1919	1.3206	CYS/2
AL	440.76	.4408	70.036	.0981	.8205	5.6464	VAL
ET	189.6	.1896	30.127	.0422	.4495	3.0933	MET
LE	334.04	.334	53.078	.0743	.6963	4.7914	ILE
EU	594.08	.5941	94.398	.1322	1.2383	8.5213	LEU
LE	500	.5	79.449	0	0	0	NLE
YR	192.68	.1927	30.617	.0429	.5547	3.8174	TYR
HE	285.32	.2853	45.337	.0635	.7489	5.1536	PHE
TOTALS*				2.132	14.5321	100	

ECOVERED NITROGEN= 82.8622862%

RY MATTER BASIS

AME OF SAMPLE----------FNIA FC
AMPLE CHROMATOGRAM NUMBER----13
AMPLE ANALYSIS DATE----------6-86
EIGHT OF SAMPLE (IN GRAMS)---.086376
AMPLE DILUTION (IN MLS)------15
ERCENT NITROGEN----------2.81202186
ERCENT PROTEIN (N X 6.25)----17.5751366

MINO CID	NMOL/ ML	UMOL/ ML	UMOL/ G	GN/ 100G	GAA/ 100G	GAA/ 100G(CP)	AMINO ACID
YS	205.72	.2057	35.725	.1001	.5223	3.2884	LYS
IS	142.68	.1427	24.778	.1041	.3845	2.4207	HIS
H3	1562.8	1.5628	271.395	.3801	.4622	2.9101	NH3
GP	500	.5	86.83	0	0	0	AGP
RG	200.16	.2002	34.76	.1948	.6055	3.8126	ARG
YS	0	0	0	0	0	0	CYS
SP	531.12	.5311	92.234	.1292	1.2276	7.7297	ASP
HR	299.96	.3	52.091	.073	.6205	3.907	THR
ER	534.8	.5348	92.873	.1301	.976	6.1453	SER
LU	1348.44	1.3484	234.169	.328	3.4453	21.6933	GLU
RO	557.6	.5576	96.832	.1356	1.1148	7.0195	PRO
LY	453.44	.4534	78.744	.1103	.5912	3.7225	GLY
LA	514	.514	89.261	.125	.7952	5.0071	ALA
YS/2	100.52	.1005	17.456	.0245	.2097	1.3206	CYS/2
AL	440.76	.4408	76.542	.1072	.8968	5.6464	VAL
ET	189.6	.1896	32.926	.0461	.4913	3.0933	MET
LE	334.04	.334	58.009	.0813	.761	4.7914	ILE
EU	594.08	.5941	103.168	.1445	1.3534	8.5213	LEU
LE	500	.5	86.83	0	0	0	NLE
YR	192.68	.1927	33.461	.0469	.6063	3.8174	TYR
HE	285.32	.2853	49.548	.0694	.8185	5.1536	PHE
TOTALS*				2.3301	15.882	100	

ECOVERED NITROGEN= 82.8622863%

APPENDIX B

RAW DATA, ANOVA TABLES

(SAS OUTPUT)

TEST H= SUGAR|TRT WITH BAT*SUGAR*TRT
SAMPLING ERROR IS CHIC(BAT SUGAR TRT)
BAT*SUGAR*TRT IS REALLY BAT*SUGAR+BAT*TRT+BAT*SUGAR*TRT

DAY=2

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: GAIN_DAY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	319	10512.49687500	32.95453566	.	.	1.000000	0.0000
ERROR	0	0.00000000	0.00000000		ROOT MSE		GAIN_DAY MEAN
CORRECTED TOTAL	319	10512.49687500			0.00000000		7.40312500

SOURCE	DF	ANOVA SS	F VALUE	PR > F
BAT	4	17.31718750	.	.
SUGAR	1	525.31250000	.	.
TRT	3	6481.05937500	.	.
SUGAR*TRT	3	447.42500000	.	.
BAT*SUGAR*TRT	28	543.32031250	.	.
CHIC(BAT*SUGAR*TRT)	280	2498.06250000	.	.

TESTS OF HYPOTHESES USING THE ANOVA MS FOR BAT*SUGAR*TRT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUGAR	1	525.31250000	27.07	0.0001
TRT	3	6481.05937500	111.33	0.0001
SUGAR*TRT	3	447.42500000	7.69	0.0007

TEST H= SUGAR|TRT WITH BAT*SUGAR*TRT
SAMPLING ERROR IS CHIC(BAT SUGAR TRT)
BAT*SUGAR*TRT IS REALLY BAT*SUGAR+BAT*TRT+BAT*SUGAR*TRT

DAY=2

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: FD_DAY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	319	7986.96796875	25.03751714	.	.	1.000000	0.0000
ERROR	0	0.00000000	0.00000000		ROOT MSE		FD_DAY MEAN
CORRECTED TOTAL	319	7986.96796875			0.00000000		19.98593750

SOURCE	DF	ANOVA SS	F VALUE	PR > F
BAT	4	228.74531250	.	.
SUGAR	1	267.36328125	.	.
TRT	3	6138.88984375	.	.
SUGAR*TRT	3	483.86484375	.	.
BAT*SUGAR*TRT	28	868.10468750	.	.
CHIC(BAT*SUGAR*TRT)	280	0.00000000	.	.

TESTS OF HYPOTHESES USING THE ANOVA MS FOR BAT*SUGAR*TRT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUGAR	1	267.36328125	8.62	0.0066
TRT	3	6138.88984375	66.00	0.0001
SUGAR*TRT	3	483.86484375	5.20	0.0055

TEST H= SUGAR|TRT WITH BAT*SUGAR*TRT
SAMPLING ERROR IS CHIC(BAT SUGAR TRT)
BAT*SUGAR*TRT IS REALLY BAT*SUGAR+BAT*TRT+BAT*SUGAR*TRT

DAY=7

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: GAIN_DAY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	319	8909.65887500	27.92996513	.	.	1.000000	0.0000
ERROR	0	0.00000000	0.00000000		ROOT MSE		GAIN_DAY MEAN
CORRECTED TOTAL	319	8909.65887500			0.00000000		4.85187500

SOURCE	DF	ANOVA SS	F VALUE	PR > F
BAT	4	100.11825000	.	.
SUGAR	1	209.62812500	.	.
TRT	3	5939.92637500	.	.
SUGAR*TRT	3	192.81137500	.	.
BAT*SUGAR*TRT	28	1148.99975000	.	.
CHIC(BAT*SUGAR*TRT)	280	1318.17500000	.	.

TESTS OF HYPOTHESES USING THE ANOVA MS FOR BAT*SUGAR*TRT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUGAR	1	209.62812500	5.11	0.0318
TRT	3	5939.92637500	48.25	0.0001
SUGAR*TRT	3	192.81137500	1.57	0.2196

WT AND FD CONSUMPTION ON SUGAR-BREAD EXP., SUMMER 1986
FNIA DEPT, OCT 1986, FARZANEH
12:15 MONDAY, SEPTEMBER 21, 1987

TEST H= SUGAR|TRT WITH BAT*SUGAR*TRT
SAMPLING ERROR IS CHIC(BAT SUGAR TRT)
BAT*SUGAR*TRT IS REALLY BAT*SUGAR+BAT*TRT+BAT*SUGAR*TRT

DAY=7

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: FD_DAY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	319	33543.68550000	105.15261912	.	.	1.000000	0.0000
ERROR	0	0.00000000	0.00000000		ROOT MSE		FD_DAY MEAN
CORRECTED TOTAL	319	33543.68550000			0.00000000		19.76625000

SOURCE	DF	ANOVA SS	F VALUE	PR > F
BAT	4	60.40675000	.	.
SUGAR	1	432.45000000	.	.
TRT	3	31691.12850000	.	.
SUGAR*TRT	3	639.87900000	.	.
BAT*SUGAR*TRT	28	719.82125000	.	.
CHIC(BAT*SUGAR*TRT)	280	0.00000000	.	.

TESTS OF HYPOTHESES USING THE ANOVA MS FOR BAT*SUGAR*TRT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUGAR	1	432.45000000	16.82	0.0003
TRT	3	31691.12850000	410.91	0.0001
SUGAR*TRT	3	639.87900000	8.30	0.0004

WT AND FD CONSUMPTION ON SUGAR-BREAD EXP., SUMMER 1986
FNIA DEPT, OCT 1986, FARZANEH
TEST H= SUGAR|TRT WITH BAT*SUGAR*TRT
SAMPLING ERROR IS CHIC(BAT SUGAR TRT)
BAT*SUGAR*TRT IS REALLY BAT*SUGAR+BAT*TRT+BAT*SUGAR*TRT

DAY=7

ANALYSIS OF VARIANCE PROCEDURE

MEANS

SUGAR	TRT	N	GAIN_DAY	FD_DAY
F	C	40	0.7250000	11.8000000
F	M	40	6.3850000	20.6800000
F	U	40	12.7850000	36.4450000
F	W	40	2.7500000	14.7900000
S	C	40	0.6200000	11.0750000
S	M	40	2.2500000	13.6700000
S	U	40	11.1600000	36.8300000
S	W	40	2.1400000	12.8400000

SAS

OBS	TYPE	GAIN_DAY	FD_DAY	NO_OBS
1	FC	0.725	11.800	40
2	FM	6.385	20.680	40
3	FU	12.785	36.445	40
4	FW	2.750	14.790	40
5	SC	0.620	11.075	40
6	SM	2.250	13.670	40
7	SU	11.160	36.830	40
8	SW	2.140	12.840	40

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE: GAIN_DAY

ALPHA=0.05 DF=39 MSE=41.0357
MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

GROUPING	MEAN	N	TYPE
A	12.785000	40	FU
A			
A	11.160000	40	SU
B	6.385000	40	FM
C	2.750000	40	FW
C			
C	2.250000	40	SM
C			
C	2.140000	40	SW
C			
C	0.725000	40	FC
C			
C	0.620000	40	SC

DUNCAN MUTIPLE RANGE TEST
FOR VARIABLE ****(GAIN_DAY)****

OBS	TYPE	GAIN_DAY	FD_DAY	NO_OBS
1	FC	0.725	11.800	40
2	FM	6.385	20.680	40
3	FU	12.785	36.445	40
4	FW	2.750	14.790	40
5	SC	0.620	11.075	40
6	SM	2.250	13.670	40
7	SU	11.160	36.830	40
8	SW	2.140	12.840	40

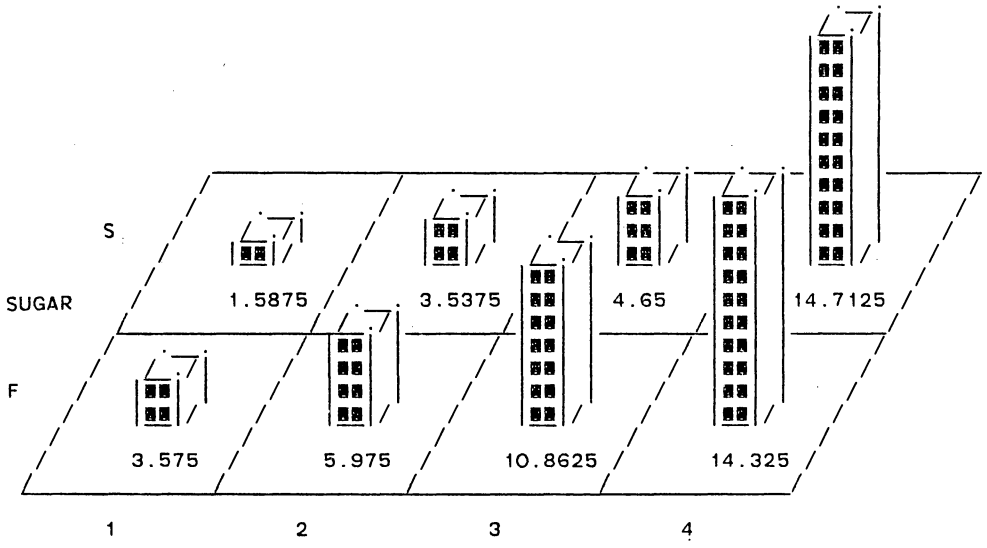
DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE: FD_DAY

ALPHA=0.05 DF=39 MSE=41.0357
MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

GROUPING		MEAN	N	TYPE
	A	36.830000	40	SU
	A			
	A	36.445000	40	FU
	B	20.680000	40	FM
	C	14.790000	40	FW
	C			
D	C	13.670000	40	SM
D	C			
D	C	12.840000	40	SW
D	C			
D	C	11.800000	40	FC
D				
D		11.075000	40	SC

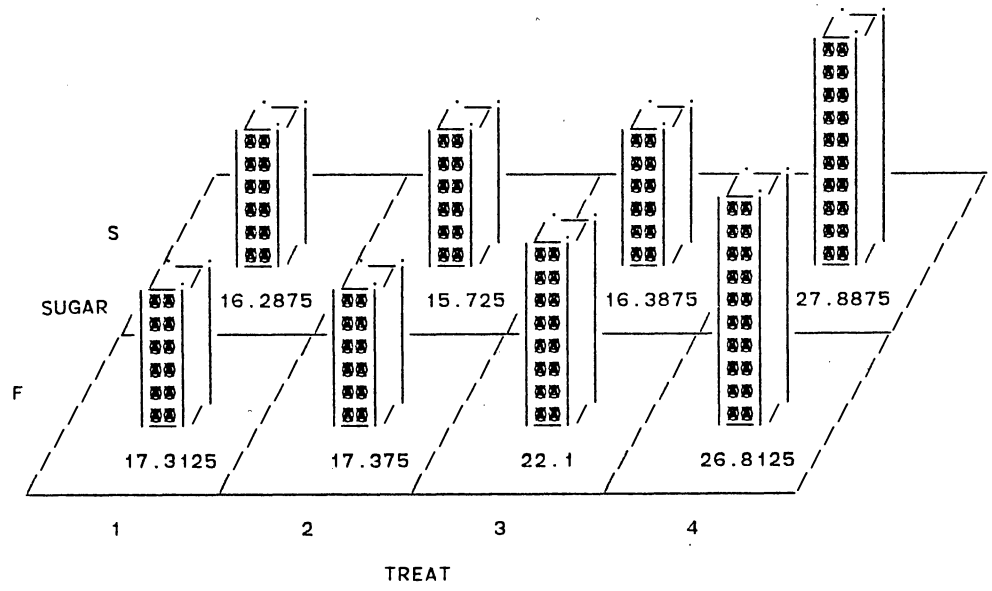
DAY=2

BLOCK CHART OF GAIN_DAY



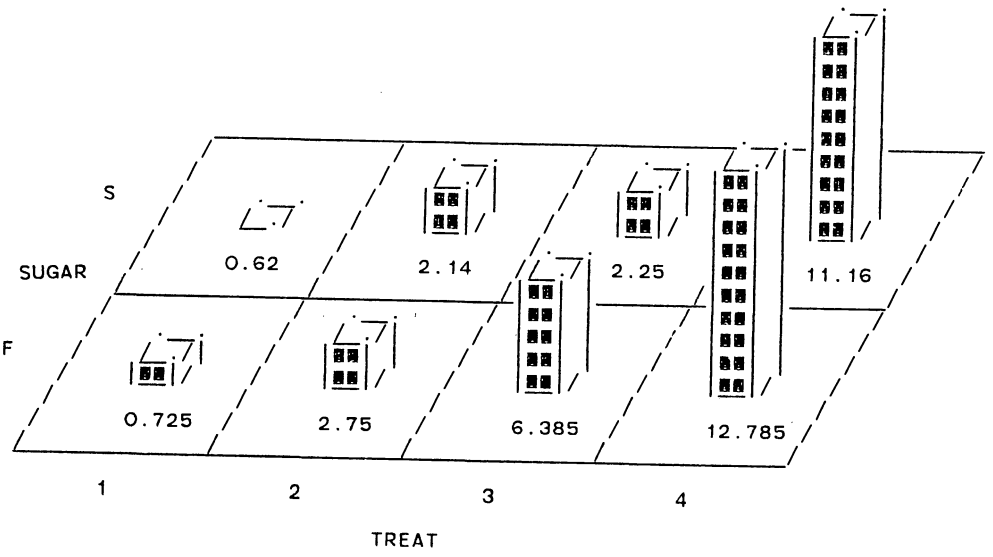
DAY=2

BLOCK CHART OF FD_DAY



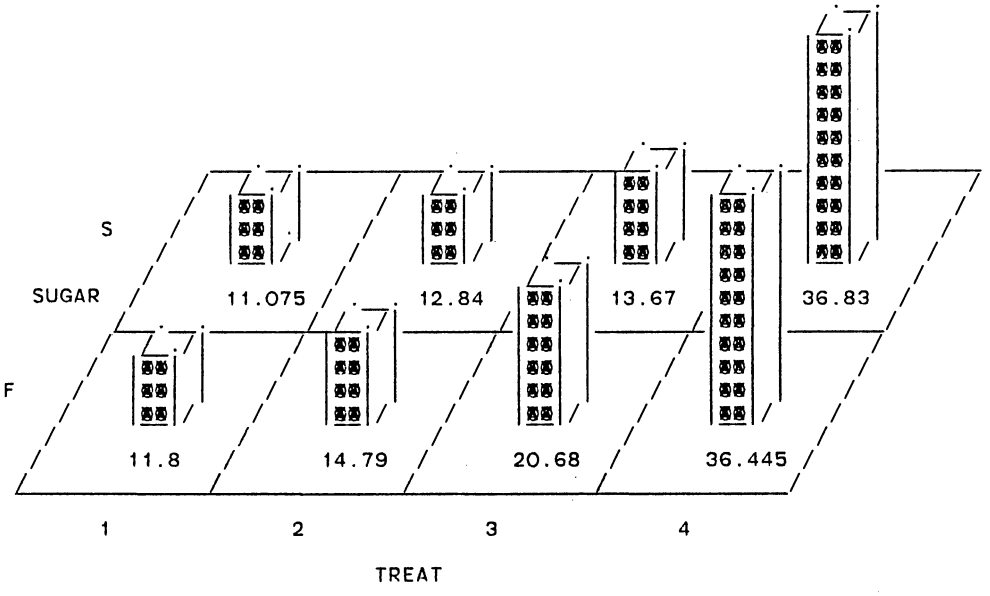
DAY=7

BLOCK CHART OF GAIN_DAY



DAY=7

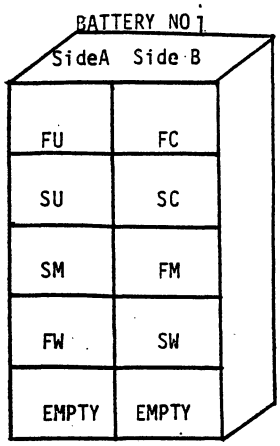
BLOCK CHART OF FD_DAY

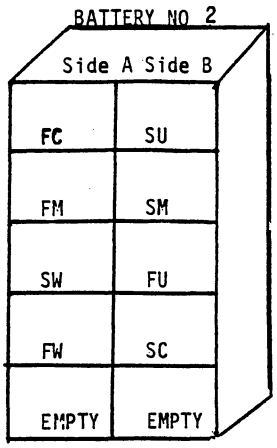


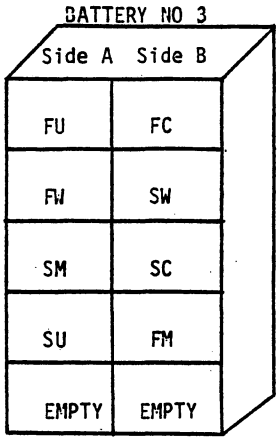
APPENDIX C

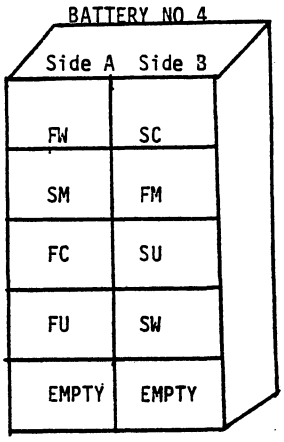
SCHEMATIC REPRESENTATION

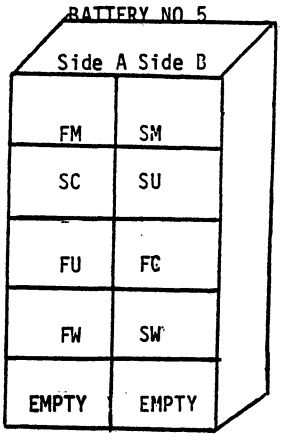
OF CHICK BATTERY


BATTERY NO 1
SideA Side B
FU FC
SU SC
SM FM
FW SW
EMPTY EMPTY


BATTERY NO 2
Side A Side B
FC SU
FM SM
SW FU
FW SC
EMPTY EMPTY


BATTERY NO 3
Side A Side B
FU FC
FW SW
SM SC
SU FM
EMPTY EMPTY


BATTERY NO 4
Side A Side B
FW SC
SM FM
FC SU
FU SW
EMPTY EMPTY


BATTERY NO 5
Side A Side B
FM SM
SC SU
FU FC
FW SW
EMPTY EMPTY

APPENDIX D

VITAMIN-MINERAL MIXED COMPOSITION

TEKLAD
A HARLAN SPRAGUE DAWLEY INC., CO.

Vitamin Mix, AIN-76A

Catalog #40077

	g/Kg
Thiamin HCl	0.6
Riboflavin	0.6
Pyridoxine HCl	0.7
Niacin	3.0
Calcium Pantothenate	1.6
Folic Acid	0.2
Biotin	0.02
Vitamin B_{12} (0.1% trituration in mannitol)	1.0
Dry Vitamin A Palmitate (500,000 U/g)	0.8
Dry Vitamin E Acetate (500 U/g)	10.0
Vitamin D_3, trituration (400,000 U/g)	0.25
Menadione Sodium Bisulfite Complex	0.15

This vitamin mix was designed without a choline source because choline bitartrate was listed as a separate item in the formula of the AIN-76 purified diet.

References: Second Report of the ad hoc Committee on Standards for Nutritional Studies (1980). J. Nutrition 110,1726. Report of the American Institute of Nutrition ad hoc Committee on Standards for Nutritional Studies (1977). J. Nutrition 107, 1340-1348.

Designed to be used at 1.0% of diet (10 g/Kg).

TEKLAD. The First Name in Research Diets.
P.O. Box 4220. Madison, WI 53711 · 608 · 274-9008

TEKLAD
A HARLAN SPRAGUE DAWLEY INC., CO.

Mineral Mix, Fox-Briggs N

Catalog #170740

		g/Kg
Calcium Carbonate	$CaCO_3$	166.6667
Calcium Phosphate, dibasic	$CaHPO_4$	473.3333
Cupric Sulfate	$CuSO_4$	0.16667
Ferric Citrate, USP	(16.7% Fe)	3.3333
Magnesium Sulfate	$MgSO_4$	50.0
Manganese Sulfate	$MnSO_4 \cdot H_2O$	4.16667
Potassium Chloride	KCl	116.6667
Potassium Iodate	KIO_3	0.16667
Sodium Chloride	NaCl	66.6667
Sodium Phosphate, dibasic	Na_2HPO_4	116.6667
Zinc Carbonate	$ZnCO_3$	2.16667

Reference: Fox, M.R.S., Briggs, G.M. (1960) J. Nutrition 72, 243-249.

1. Recommended use level in chick diets - 6.0%. This mineral mix also has been used in mouse and guinea pig diets at the same level. However, guinea pig diets are further supplemented with potassium acetate (25.0 g/Kg) and magnesium oxide (5.0 g/Kg).

TEKLAD
A HARLAN SPRAGUE DAWLEY INC., CO.

Complete Modified Glista Chick Salts

TD 73007

		g/Kg
Calcium Carbonate	$CaCO_3$	55.94
Calcium Phosphate, tribasic		522.102
Potassium Phosphate, dibasic	K_2HPO_4	167.819
Sodium Chloride	NaCl	164.09
Magnesium Sulfate	$MgSO_4 \cdot 7H_2O$	65.263
Manganese Sulfate	$MnSO_4 \cdot H_2O$	12.12
Ferric Citrate		9.323
Zinc Carbonate		1.865
Cupric Sulfate	$CuSO_4 \cdot 5H_2O$	0.373
Boric Acid		0.168
Sodium Molybdate	$Na_2MoO_4 \cdot 2H_2O$	0.168
Potassium Iodide	KI	0.746
Cobalt Sulfate	$CoSO_4 \cdot 7H_2O$	0.019
Sodium Selenite	Na_2SeO_3	0.004

Designed for use at 5.37% of chick diet.

VITA 2

Farzaneh Katkhordeh

Candidate for the Degree of

Master of Science

Thesis: EFFECT OF NON-ENZYMATIC BROWNING OF BREAD ON THE GROWTH RATE OF CHICKS

Major Field: Food, Nutrition and Institution Administration

Biographical:

Personal Data: Born in Abadan, Iran, November 18, 1959, the daughter of Ali and Malihe Katkhordeh; married Feridoon Mehdizadegan; one daughter, Ida Mehdizadegan.

Education: Graduated from Conway High School, Conway, Arkansas, in May, 1978; received the Bachelor of Science degree in Food and Nutrition from University of Arkansas in December, 1983; completed requirements for the Master of Science degree at Oklahoma State University in December, 1987.

Professional Experience: Graduate Research Assistant, Food, Nutrition Institution Administration Department, Oklahoma State University, August, 1985-December, 1986; laboratory technician I, Food, Nutrition Institution Administration, Oklahoma State University, December, 1984-December, 1987.

Professional Organizations: Oklahoma Dietetic Association, Institute of Food Technologists, American Dietetic Association, Phi Upsilon Omicron.

Honors: Phi Kappa Phi.